A CASE STUDY FOR A LARGE MANUFACTURING PLANT

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ENERGY CONSERVATION

A Case Study For A Large Manufacturing Plant

by

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B.S. University of Kansas
(1966)

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Submitted In Partial Fulfillment

of the Requirements for the Degree

of

Ocean Engineer

and

Master of Science

at the

Massachusetts Institute of Technology
June, 1974

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Submitted to the Department of Ocean Engineering on May 10, 1974, in partial fulfillment of the requirements for Degrees of Ocean Engineer in Ocean Engineering and Master of Science in Mechanical Engineering.

ABSTRACT

The methods of formulating, implementing, and evaluating a conservation program in a commercial building or light industrial plant are examined in this paper. The results of one case study are also presented.

In commercial and light industrial applications, most energy is consumed to maintain proper environmental conditions; light levels, heat levels, and fresh air levels. Most buildings today expend too much energy on these services. A co-ordinated program to maintain environmental conditions at levels pointed out in this report could save as much as 20% each year in energy consumption.

This report presents a method that can be used by many commercial and light industrial concerns to establish a conservation program. Guidlines are presented that can be used to examine environmental conditions and determine how they must be changed. A system of program analysis is also presented.

Results of this study show that saving 20% is possible, but motivation of the company and workforce will be a problem. The report also concludes that new buildings can be made more enrgy efficient if energy conservation is kept in mind during building design.

ACKNOWLEDGMENTS

First, I would like to acknowledge the patience and understanding of my wife and son during my entire time at M.I.T. The lost weekends, no Dad to play with at night, and the constant requests for quiet are over now, and our homelife can return to normal.

I would like to thank my Thesis Advisor, Professor Leon Glicksman for his continuous help. Without his comments and suggestions, this thesis would not have attained its final polish. Mr. John Rudy of Raytheon also deserves much credit for the thesis. He started me on the case study and was always ready and available to help me work out some of the details and cut red tape. Mr. Bill Jones of the M.I.T. Energy Lab was a great help. He was always willing to share ideas and keep me on the right track with the case study.

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I

ENERGY PROBLEMS

1-I. Solutions to the Energy Crisis

The energy crisis may be attacked in several ways, and it is most convenient to class them in the three following categories.

A. New Energy Sources

We must find new sources of energy. These may be more of the oil and gas we use so much of now, or they may be completely new sources of power such as solar energy.

B. Improved Conservation Efficiency

We must make the conversion of energy from oil or gas to electricity or other more familiar forms of useable energy as efficient and as economical as possible.

C. Better Use-Habits

We must change consumer's use-habits so that whatever the source of energy he uses it as wisely and sparingly as possible.

There is much that can be done to find new sources of energy. Exploration for more oil and gas can be increased. Methods can be perfected to liquify and gasify coal and make it a clean environmentally acceptable fuel. Oil shale can be developed. This will provide more conventional oil and gas. Solar energy, nuclear power, and fusion reactors will provide us with energy sources that are not so dependent on expendable resources. Unfortunately, all these things take time. They are long term solutions that cannot solve

our immediate problem.

Oil and, to a certain extent, gas are not used directly by man in the form in which they are extracted from the earth. They must be converted to some other useful form of energy: gasoline, heating oil, electricity, mechanical work, etc. The second category of solutions to our energy problems involves improving this conversion efficiency and making it more economically able to produce environmentally acceptable clean fuels. Most of these conversion devices, when operated properly, are as efficient as the present state of the art allows. This efficiency can be improved with time, but it also is not a short term solution to the energy crisis.

It is the inefficient use and poor maintenance of existing machinery that causes the greatest inefficiency in the conversion process. To improve this, one must tell the people operating the machines how best to do the job.

The third category of solutions to our energy problems deals with this inefficient use of existing machines. These are the short term solutions, and they deal with the public and how it uses the final energy products.

Over the past several years, companies specializing in telling industries how to reduce their energy consumption have shown that reductions as large as 20 percent are possible without effecting the industry's production (1)*. If energy waste as large as this can be generalized to all consumers, elimination of this waste would

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* Number in parentheses refers to references contained on page.

certainly reduce the magnitude of our energy shortages. A short term solution then to our energy problems is to eliminate this waste by providing the public with conservation programs that will allow it to consume energy more efficiently.

A combination of all the solutions to the energy crisis is of course what is needed, but one must realize the time frame involved. Only the last set of solutions is short term and can help immediately. This report will deal only with these short term solutions.

1-II The Short Term Solutions

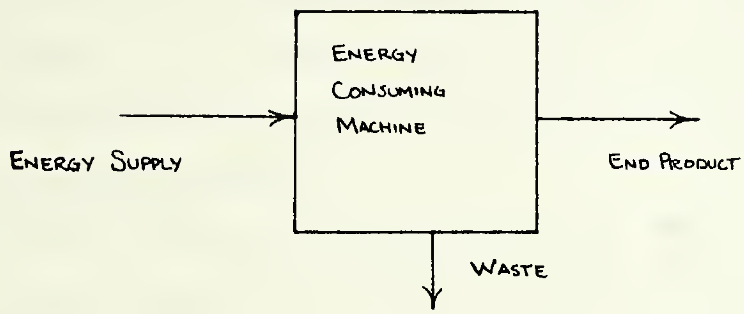
The short term solution to the energy crisis is to change and improve the public's use-habits of existing energy supplies. This category of solutions can be broken into two parts: one dealing with the machines, operating procedures, and hardware, and the other dealing with the people who operate the hardware. It is relatively easy to analyze the consumption hardware and recommend changes and new procedures that will consume less energy, but these procedures are worthless if the people are not motivated to follow them. Each problem is unique and must be treated separately.

This report will not deal in detail with the problems of public motivation. An example of the rise and fall of motivation through an energy "crisis" will be given, and some general conclusions will be drawn in the final chapter regarding motivation and possible solutions to the problem. It is sufficient to say that one must realize motivation is an integral part of any conservation program and it

must be given serious consideration.

The procedure and hardware aspects of the short term solutions are much more tangible than the motivation problems. These solutions can all be formulated by an examination process that can be termed "modify the machine, modify the end product".

The following diagram illustrates the energy consumption process.



Increasing the amount of energy supplied to the machine is not a short term solution to energy shortage problems. Therefore, one must concentrate his effort on the "machine", the "waste", and the "end product". Several things can be done. The waste can be reduced by either modifying the machine or operating it differently to use less energy. Or, the end product; heat, cooling, work manufactured goods etc., can be changed if necessary to reduce energy consumption. It is this general analytical approach that will be applied in Chapter 2 to give one a general solution technique that can be applied to a large manufacturing plant.

1-III Report Objectives

This report will deal only with the short term solutions to the energy crisis as they apply to the use-habits of a manufacturing plant. A step by step method of formulating and implementing a conservation program in a light manufacturing or commercial building is not available. This work was undertaken to provide this information. There is also little quantative information available on expected savings from any conservation program. This report will provide an example of a conservation program in action for a large manufacturing plant and will give a comparison of projected vs. actual results of this program.

Aside from the obvious objective of conserving as much as possible without interrupting production in the particular plant studied the following are this report's objectives:

A. To provide a general method of attacking a conservation program. This report will outline a method to analyze an energy consumption system, and determine what can be done to conserve energy.

B. To provide specific details on formulating a conservation program in a manufacturing plant. A complete analysis will be made of an existing plant and the results presented.

C. To provide a list of expected large energy consuming devices so that anyone can look at his particular application and know which machines he should study first.

D. To provide the specific mathematical and analytical tools

needed to conduct a detailed study.

E. To provide the methods of analyzing conservation program results and determining energy savings.

F. To promote the spirit of a "new way" of looking at a building, both existing and new construction, as an energy using system that must be made to work as efficiently as possible.

In short, this report provides the tools necessary to formulate, install, and evaluate a conservation program, and gives a detailed example of the process.

1-IV Report Outline

Chapter 2 details the general procedures to be used in setting up an energy conservation program in a manufacturing plant. Most of the programs are concerned with saving energy with environmental services equipment.

Chapter 3 is an example of the procedures of Chapter 2 applied to a real situation. This chapter explains an actual conservation program through its formulation and implementation phases.

Chapter 4 presents the results of the conservation programs with the savings broken into three major categories; heating savings, air change savings, and miscellaneous savings.

Chapter 5 presents the conclusions of the report with some suggestions for solutions to the problems of motivation and poor plant construction.

II

CONSERVATION PROCEDURES

2-I Manufacturing Plant Conservation

The total national energy consumption breaks down as follows; 14.4 percent for commercial building services, 19.2 percent for residential services, 41.2 percent for industrial processes, and 25.2 percent for transportation (2). From the residential and commercial services, 20.4 percent of the national energy consumption is for heating and air conditioning alone. A 20 percent reduction in this heating and air conditioning requirements would save a total of 4 percent of the annual energy requirements. Cutting the industrial process requirements by a like 20 percent would save a additional 8.2 percent. These two actions alone would save 12.2 percent annually and they are both considered easily obtainable.

One only has to open the Sunday papers or pick up the latest utility company brochure to find a list of ten to twenty energy saving ideas. These ideas are sound and they can be applied to many situations. The trouble is, no one knows exactly how much these actions will save in a particular application, nor how much they will interact. Since the end result, the savings, is the measure of any conservation program's success, these questions must be answered before a conservation plan is instituted.

This chapter is a general outline that may be followed to formulate and institute a conservation program. It gives the general pieces

of a program and tells how to make them fit a particular application. A technique to estimate savings before the program is started and to measure actual savings after the program is instituted will be presented.

One thing will become clear in a conservation study like this; every application is unique. The programs may be made up of the same general parts, but the proportions and results will be different in every case. The machinery that accomplishes the same tasks in two different plants will not be the same. It will either be manufactured by a different manufacturer or controlled by different controls. It will be in different surroundings, and it will certainly be operated by different people with different operating techniques. In order to optimize, or fit, a program to a particular building or plant, a careful study must be made. The person or persons formulating the conservation program must understand the particular building.

2-II <u>Program Study Outline</u>

The following outline contains the steps necessary to complete a conservation study and get a conservation program working in any plant.

A. The plant being studied must first be throughly understood. The work force, the products manufactured, the energy consumed, and the machines that consume the energy must be identified.

B. Historical energy use data must be collected and analyzed.

This information will give an insight into howmuch energy is being used and, in a very general sense, for what it is being used.

C. The building's energy consumers must be ranked in very broad categories such as lighting, heating, cooling ventilation, and manufacturing, so that the areas that consume the most can be identified and examined first.

D. The building's heat gains and heat losses must be analysed. Heat and cooling will use a significant part of the energy consumed, therefore one must know how much energy is required for these fuctions.

E. New operating procedures must be made and equipment modifications recommended. Estimates must be made of how much these changes will save.

F. Finally, the savings program must be implemented and its results evaluated. After the evaluation one can then modify the program, if needed, for refinement, and set up the organization necessary to see that the program continues to work.

2-III Understanding the Plant

The first order of business for anyone making a conservation study is to throughly understand the plant being studied. A check list of questions such as that in Appendix A will help him gather needed information. One should at first try to understand the broad questions of - How much energy is used? In what form? Where is the energy used? One must also understand the manufacturing process and

the products manufactured.

The energy consumed by the building will fall into two general categories. One is the energy used in direct production support. The other is the energy used to maintain plant environmental conditions, hereafter called environmental services energy. How this energy split applies to one particular plant should be determined first.

On the average, this energy split for industrial and commercial concerns is 26 percent for environmental services and 74 percent for production support (3). When one removes heavy industry; primary metals, chemical, and oil refining operations, from this category, they use about half of the energy consumed and it all goes to product support, the split for the remaining commercial and light industrial consumers becomes 52 percent for environmental services and 48 percent for production support. As one can see, the majority of commercial and light industrial cases use more energy for environmental services than for production support.

This report will deal in much more detail with the energy conservation actions possible with environmental services because they are relatively easy to generalize and they represent the largest energy consumer in the majority of plants. The production support process is not easy to generalize, but none the less, if its energy consumption is high, conservation programs in that area must be examined.

2-IV Analyzing the Plants Historical Energy Use Data

When one analyzes the plant's past energy use data, he is trying to learn a little more about the plant and expand the base on which he will build the conservation program. The use data can tell several things. It can point out seasonal variations that can be tied to heating and cooling. It can show how much power manufacturing consumes by daily variation. And, the analysis is the only step that will tell exactly how much energy has been used in the past.

2-IV-A Sources of Data

Historical information will be available in several forms. Electrical data will probably be the most complete. For most plants there will be a permanent recording device that continuously records average KVA used in a 15 or 30 minute period, depending on the meter. This record, usually a paper tape, will be kept either at the plant or the electric utility company. This is probably the only record that can provide an hour by hour accounting of energy use.

For gas and oil, the monthly meter readings on bills will have to provide use data. There is not normally any finer grain information available for these two sources of energy. For reasons that will become apparent when analysis of this data is discussed, this bill information will probably be adequate.

One will also need weather data for the analysis. Most of this information can be collected from a local air port or utility company. One will need both an hour by hour temperature accounting for the electrical analysis and a mean degree days per day information for

the oil and gas analysis.

2-IV-B Analysis

2-IV-B(1) Electrical Data Analysis

Electrical information will come in the form of a tape recording average KVA over a 15 or 30 minute period. The information must be converted from KVA reading to KW reading with the building's power factor. In most cases the power factor is so near 1.0 that no conversion will be necessary.

Since the electrical power for a building is used for many tasks it is necessary to use all of the detail available in the tapes for the analysis particularly if electricity is used for heating. The tape data should be graphed, on an hourly basis with 24 hours on a graph, for representative periods of a year. These graphs can then be used to see seasonal and daily variations. Those days when the outside temperature is from 60 to 65°F should have no heating or cooling requirements. This is a very rough approximation. If a building is quite large and has areas of very high heat gain, it is quite possible to have both air conditioning and heating required at the same warm outside temperature. The coldest days in the middle of winter should represent maximum heating. The difference of the average KW for these days will give an indication of the amount of energy that goes into heating. If one divides this difference by the difference in outside temperature on those days, one will get a rough idea of how heating requirements vary with outside temperature. Once again the accuracy of this approximation depends on

the uniformity of the building's internal heat gains. If they are very uniform, this should be a close approximation.

The same process can be carried out for cooling with warm days in mid-summer used as a cooling day maximum. There are other techniques, such as regression analyses, that can be used to examine the information, but the object of the analysis is the same; to get an idea where the energy is being consumed and in what proportions. As well as how this power consumption varies with weather and production conditions.

2-IV-B(ii) Oil and Gas Data Analysis

In most commercial and light industrial cases, oil and gas is used for heating. For this reason, monthly bill information will suffice for use analysis. A good indication of how use varies with outside temperature, the object of the oil and gas data analysis is obtained by normalizing the monthly bill use data to the number of degree days in the billing period. The result, the number of gallons or cubic feet per degree day, will be a bench mark against which future conservation programs can be judged. Any changes in the heating requirements of the building caused by conservation programs will show a drop in the energy per degree day.

2-IV-C Production Changes

For a complete analysis one should also note any production changes or work force changes that took place during the evaluation period. These changes might have caused increases in power consumption and the magnitude of the change compared with the production

change can provide information about the manufacturing process. In the case of electrical energy, the manufacturing load will show up as the constant daily variation of KW readings.

2-V Ranking of Energy Consumers

By the time historical use information has been analyzed, energy consumers should be able to be ranked according to their share of the total **annual** energy use. It will then be obvious which general category of consumer uses the most energy and offers the greatest potential for savings. It is suggested that environmental services should be addressed first if they consume over 45 percent of the annual energy bill. The savings programs associated with these areas are much easier to formulate than production support programs and they offer immediate results.

2-VI Analysis of the Building's Heat Loss

This is a step that is specialized to the heating and cooling system analysis but it is a mojor tool for formulating most savings programs, therefore it is presented in this separate section. The objective of the analysis is to calculate from building characteristics how much heat is lost or gained by the plant building during certain outside weather conditions. And, most important, where the heat is lost. The analysis of historical usage data cannot give the detailed information.

Heat can be lost or gained by two major methods. First it can be simply trasnferred through the exterior wall or outer surface of

the building. Second, it can be brought into or taken from the building with hot or cold air. The first mechanism is limited by the insulating quality of the building, the second by the air tightness of the building.

2-VI-A <u>Heat Transfer Through the Building's Outer Surface</u>

The conduction heat loss can be very simply estimated by examining the building construction and then putting the results into the conduction heat transfer equation.

$$Q = \varepsilon U A \Delta T$$

Q = Heat loss or gained per unit time (BTU/HR)

U = Heat transfer coefficient (BTU/HR-$^{\circ}$F-Ft^{2})

A = Area of heat transfer surface (Ft^{2})

ΔT = Temperature difference between outside and inside ($^{\circ}$F)

Table 2.1 lists some representative U factors for various materials and surfaces. Detailed information can be found in the <u>National Electrical Manufacturing Association Manual for Electric Comfort and Heating</u> (4) and the <u>ASHRAE Heating Ventilation and Air Conditioning Guide</u> (5).

In order to use this equation, one must break the building down into like heat and transfer areas, find a U factor for these areas, multiply the U factor by the A for all these sections, and add the UA product for all sections to get a final UA for the building. This UA for the building will now allow estimation of the reduction in heat loss that will be effected by lowering inside temperature. Finally,

if one estimates the overall efficiency of the heating system, this UA value can be used to determine energy savings.

It is important to note that the heat loss in a building, assuming constant UA, is linear with ΔT. In other words, lowering ΔT by a particular percentage on any given day will lower heating requirements by that same percentage. This simple relation can be used to estimate savings in the preliminary analysis.

2-VI-B Air Change Heat Loss

The heat lost or gained by the air exchange, from the building to the outside, can also be determined by a relatively simple process. First an estimate of the number of hourly air changes the building experiences must be made. This information must be extracted from the building manufaturer's design information, or it can be estimated. If the building has installed exhausts, the combined rated exhaust capacity should be very close to the amount of air pumped from the building, assuming no excessive leakage at windows and doors. This number, usually in cubic feet per minute, converted to cubic feet per hour and divided by the building's volume, will give the number of air changes per hour. If there are no installed exhausts and no builder's information available, the air change rate can be estimated.

There is little quantative information available to allow one to estimate air infiltration or turnover rates for buildings without forced exhausts, but the following are some broad guide lines. The National Electrical Manufacturers Manual for Electric Comfort Heating(6)

and the <u>ASHRAE Heating Ventilation, and Air Conditioning Guide</u> (7) suggest that a tightly constructed residence will experience 1 to 1.5 air changes per hour. An equally tight large building with a smaller surface area to volume ratio will experience about 0.5 to 0.75 air changes per hour. Most new buildings with little window area and few doors will fall in the lower part of this range. An old building with loose fitting windows and doors could have an air change rate of up to 2 per hour.

Air change rate can be converted to an energy requirement per degree of ΔT.

$$E = N\ V\ 0.0183\ \text{BTU/ft}^3\text{-}^{o}\text{F}$$

E = Energy requirements per hour per degree of ΔT (BTU/Hr-^{o}F)

N = Number of air changes per hour

0.0183 BTU/Ft^3-^{O}F = Volumetric specific heat of air

V = Building Volume (ft^3)

This E is in the same form as the conduction UA and can be added to it to give total building heating energy requirements.

The final equation that describes the building heat loss or gain will be:

$$Q = (UA_{\text{total}} + E) \times \Delta T$$

This equation can be used to determine how changing any or all of its components will reduce the Q value and therefore the energy consumption.

Solar radiation will have little effect on this equation. Wind will affect the equation according to the size of the U factor. If the U factor is large, then wind can have an effect, such as with glass. If the U factor is low, wind will have little effect.

2-VII Formulating Savings Programs

There is now almost enough information to put together an energy conservation program.

One must also make a study of the environmental service energy consumption. Some of this study was accomplished when the heat loss calculations were made, but there is more that must be determined. Light levels must be determined to see if they can be lowered. And, air conditioning and heating systems must be examined. It is possible that the heating and air conditioning systems are operating at the same time with poor control co-ordination. Chapter 3 will provide an example of the magnitude of this saving.

The studies made of both the production support energy and environmental services energy are in technique the same, but the conservation program formulation is different. The production support program will not be made up of a few simple rules that can be modified and applied to all processes; the environmental service conservation will be. For this reason, only the environmental service conservation will be dealt with in detail in this report. The programs for environmental service energy consumption reduction can almost always be made of only a few general parts. These parts will be modified so they fit together and meet the requirements of a particular building.

but nonethe less they are generally the same.

2-VII-A General Environmental Service Conservation Programs

2-VII-A(1) Lighting Programs

For most part, buildings are over lighted. The objective in lighting conservation is simple. One should attempt to provide only the necessary illumination with a minimum of power consumption. In the long run, this can mean replacing lighting fixtures with units that are very efficient and have provisions for removing heat in the summer, but in the short run, it means turning off un-needed lights or relocating some fixtures. One must use a light meter and monitor the lighting levels throughout the plant. It should be insured that no more than the exact amount of light recommended and needed to do the job is provided. As a maximum no area should have more lighting available than is recommended by the Illuminating Engineering Society, Recommended Levels of Illumination (8). Table 2.2 contains a few of these recommendations. The process will be trial and error with feedback from the work force guiding how much light levels can be reduced. Every attempt should be made to lower the levels as low as possible with the maximum being that of the I.S.E Recommended Levels.

Lights should also be turned off when not in use. With the cost of electric power today, this means when not in use for any period of time. The money expended for bulbs which have had their lives shortened by many starts will be more than offset by the cost of electricity saved. (9)

In estimating the saving resulting from light level reductions and turnoff, there is a seasonal aspect. In the heating season the lights provide heat. The heating system is a more efficient and cheaper method of providing heat but none the less, the lights provide heat. Therefore, when estimating the savings realized by turning off lights in winter, one can not expect to save 100 percent of the KW of lights not used. The exact percentage of actual savings will vary with light type and placement but a good first guess would be 10 percent of the KW turned off. The other 90 percent is useful heat. For this reason, one might think that light reduction programs are not useful in the heating season. This is not entirely true for as will be shown, light reduction is absolutely necessary in the cooling season and it is easier to design a program that will continue year round. And, turning off lights in the winter will shift heating requirements to a more efficient source of heat, the building's installed heaters. If the plant is heated by electric resistance coils, the increase in efficiency will be very small. However, if the plant is heated directly with fossil fuel burners, the increase in efficiency can be quite large.

In the spring, summer, and fall, on any day that air conditioners must operate, lighting reduction is much more important. The heat generated by the light on these days must be removed by the air conditioning. Therefore, over 100 percent of the KW of reduced lighting can be saved. An air conditioner will expend about 0.5 KW of energy to expell 1.0 KW of heat. Turning off 1.0 KW of lights will

therefore save 1.5 KW of energy in the cooling season.

2-VII-A-(ii) Heating Programs

In the short term the only thing one can do with the heating system to conserve energy is to turn down the thermostat. It should be insured that all heating equipment is in good working order and that controls are accessible only to authorized personnel but little more than lowering the inside building temperature can be done to reduce conduction heat loss. The possibility of night temperature set back, lowering the temperature even more at night can be investigated. One will have to take the building's thermal inertia into account and insure that thermostats are raised soon each night enough to have temperature at required levels by morning. In the long term, such things as supplementary insulation can be added and drapes or blinds to windows.

2-VII-A-(iii) Air Conditioning Programs

In air conditioning, as in heating, the object of the conservation program is to lower the inside to outside temperature difference. In the cooling season, however, the thermostats must be raised. But, because air conditioners remove heat from the building regardless of its source, one must also reduce internal heat gains. High heat producing processes must be isolated from the rest of the plant, and large glass areas must be screened with drapes or shades. These two things, raising the thermostat setting and eliminating internal heat gains, can save as much as 30 percent of the summer air conditioning requirements as shown in Chapter 3.

2-VII-A-(iv) Ventilation and Air Change Programs

Ventilation or air change is a very important energy conservation area in all buildings and must be examined carefully. In most cases the energy expended each hour to heat or cool fresh outside air before it is brought into the building is as much or more than the energy that replaces heat lost or gained through conduction. If the thermostat is raised or lowered, the amount the air must be heated or cooled is reduced, but the real payoff in a ventilation savings program is to reduce the amount of air turned over each hour.

When the building is unoccupied, all ventilation should be turned off. During occupied hours, the ventilation should be the minimum amount required.

There are few guide lines as to what constitutes adequate ventilation. The ASHRAE Heating, Ventilation, and Air Conditioning Guide (9) is one source of recommended ventilation rates. Table 2.3 gives some of these recommendations .

It is suggested that for all areas that do not have toxic fumes present these recommendations be met.

When toxic fumes are present, the Occupational Safety and Health Act is the law that must be followed. It requires that ventilation remove the toxic substances so that human exposures are kept below certain specified limits. If there are no persons in the areas and no fire hazard will be presented by reducing ventilation for the area, then the ventilation should be reduced. If ventilation is required

when people are not present, it should be unheated air.

2-VIII Implementation of Programs and Evaluation of Results

After one has formulated programs, he must establish a control week or number of days so that when programs are implemented, he can judge their effectiveness. This period should be a time when no conservation programs are in affect. During this time, recordings should be made of inside temperature, outside temperature, plant population and power consumption. If the plant uses oil or gas, the meter or tank levels must be taken at the beginning and the end of the control period. Any time for which such information is available will be satisfactory. If past consumption periods are well documented, they can serve as the control. The data will be used as the bench mark against which actual conservation programs will be judged.

When the control data has been recorded, then the conservation program can be put into effect.

2-IX Following Chapters

This chapter has been kept general so that the major points of a conservation study can be brought out. The next chapter will use this general technique in a case study of an all electric manufacturing plant. Details of how the various steps were performed will be covered in Chapter 3. Chapter 4 will give the results of the study.

TYPICAL "U" FACTORS

Surface	U Factor (BTU/Hr-°F-Ft^2)
Walls:	
No insulation	0.50
Heavy insulation	0.04
Ceilings:	
No insulation	0.61
Heavy insulation	0.04
Floors:	
Concrete slab (in terms of floor perimeter)	
No Edge insulstion	0.85
Edge insulated	0.51
Glass Area:	
Single glass	1.30
Double glass	0.55
Triple glass	0.40

Table 2.1

RECOMMENDED LEVELS OF ILLUMINATION

Area	Light Level (footcandles)
Manufacturing Assembly Areas	
Rough Easy Seeing	30
Medium	100
Fine	1000*
Office Areas	
Detailed Drafting	200
Reading or Transcribing	
Good Quality Handwriting	70
Corridors, Elevators, etc.	20

* This level may be obtained with spot lighting

Table 2.2

ASHRAE RECOMMENDED VENTILATION RATES

Condition	Recommended cfm/person	Minimum cfm/person
No toxic Fumes People not Smoking	7.5	5.0
No toxic Fumes People Smoking	40.0	25.0

Table 2.3

TABLE 2.4

Typical Savings

Total Heat Loss : 100 KW/^{o}F

Heating Year : 8000 Degree Days (to 75 ^{o}F)

Cooling Year : 600 Degree Days (to 75 ^{o}F)

Ventilation Heat Loss: 75 KW/^{o}F

Total Lighting : 1600 KW

Cooling Require: 0.5KW to remove: 1.0 KW of heat

I. Heat Saving:

Total Heat Required:

8000 Degree Days x 100 KW/^{o}F x 24 Hr/Day

= 19,200,000 KWHR

10 ^{o}F Thermostat Lowering for 215 Days Saves:

10 ^{o}F x 215 Day x 100 KW/^{o}F x 24 Hr/Day

= 5,160,000 KWHR or

26.9% of Heating Requirements

II. Ventilation Reduction Savings:

25% Ventilation Reduction Saves

0.25 x 75 KW/^{o}F x 8000 Degree Days x 24 HR/Day

3,600,000 KWHR or

18.8% of Heating Requirements

(Table 2.4 Cont).

III. Lighting Reduction Cooling Savings:

75% Reduction for 10 Hours per Day of Cooling Season

Saves:

0.75 x 1600 KW x 10 Hrs x 150 Days

= 1,800,000 KWHR

Cooling Savings is ½ of Light Heat

= 0.9 x 0.5 x 1,800,000 KWHR = 810,000 KWHR

Total Cooling for Lights and Weather is:

100 KW/°F x 600 Degree Days x 24 Hr/Day x 0.5

= 720,000 KWHR

Total Cooling for Lights is:

1600 KW · 24 Hrs · 150 Days · 0.5

= 2,880,000 KWHR

Total Cooling is:

2,880,000 KWHR + 720,000 KWHR

= 3,600,000 KWHR

Total Saved is:

810,000 KWHR or

22.5% of Cooling Load

III

CASE STUDY

3-I General

This chapter is the application of the method outlined in Chapter 2. Some of the steps suggested in Chapter 2 will not be followed exactly in this chapter , since the method outlined in Chapter 2 was formulated as a result of this case study. As an example, the initial information gathering questionaire came as a result of this study.

This case study examines a year around program of conservation, but only the winter portion of the program has now been implemented. Program formulation and yearly savings estimates are made in this chapter, but the results discussed in Chapter 4 are only for the winter program.

3-II Plant Characteristics

The plant, the Ratheon Missile Systems Division Plant in West Andover, Massachusetts, is a relatively new plant; less than four years old. Table 3.1 lists the building's characteristics. The plant complex consists of two buildings. One building is an assembly building where the electronics components for the missile product as well as the missiles themselves are assembled. The other building, connected to the assembly building through a one floor cafeteria, is an administrative building. The plant is totally electric and purchases its electricity from the Massachusetts

Electric Company.

There is no heavy machinery used in the plant; most of the manufacturing concerns fabricating and assembling electronics components. The component parts are assembled into the final missile and then tested. None of these processes require heavy machinery.

The average work force is 5,000 people with a majority of them working the day shift. There are virtually no administrative personnel working a night shift, and only about 1,000 workers work a night shift in the assembly part.

The administration building and the assembly building have separate heating and cooling systems that are isolated from each other. Both buildings are heated by resistance coils in the air handling system. The administrative building also has 218-1KW perimeter heaters. Cooling is accomplished by 9 chilled water units on the administrative building and 24 independent direct expansion units on the assembly building. The administrative building perimeter units also have a cooling mode.

3-III Preliminary Investigation

The plant uses only electricity and in an average year consumed 51 x 10^6 KWHR's. There is no major machinery or other direct production support energy consumers therefore it was immediately assumed that a majority of energy was used for environmental services; light, heat, cooling and ventilation. It was felt that these areas offered the greatest possibility of return in an energy conservation program.

A quick check of light and temperature levels showed that they were too high. The average temperature level in the winter was 76 to 78°F and in the summer a cooler 75°F. Light levels were far above the I.E.S. suggested levels. Office areas were as high as 210 footcandles with corridors and stairwells registering 150 footcandles. Manufacturer's design specifications indicated that the initial design was to a uniform 150 footcandles in all areas. This is over the suggested levels in most areas.

This preliminary survey caused a general picture to take shape. It appeared that the most energy could be saved with the environmental services. An analysis of the historical energy usage was made next.

3-IV Analysis of the Historical Energy Usage Data

This particular building had excellent past energy data. A permanently recording demand meter had been installed in the plant when it was built and this meter provided paper tapes with 15 minute average KVA levels for a period of about three years. These tapes provided the detailed information necessary to do two things. First the tapes provided daily energy consumption data that was plotted on an hourly basis, one day per graph, for representative times of the year. Figure 3.1: A and B show some of these graphs. Figure 3.2 shows monthly energy consumption. The second thing was a regression analysis of winter KW requirements versus outside temperature.

First the plot information. One thing became clear from the

daily charts; heating energy was a large part of total energy requirements. A cold day in January had an average energy consumption of 240,000 KWHR's and a no-heating day in Fall about 90,000 KWHR's. These two days, when compared, showed that heating requirements could more than double the power requirements. These two days also give an indication of how heating varied with outside temperature, The cold winter day represented about 60 degree days and the fall day about 10 degree days (for this plant, fifty-five degrees is the point where heating systems are no longer required with internal heat gains providing all the required heat). Comparing these two numbers showed that heating requirements varied by 3,000 KWHR/degree day or 125 KW/°F. This number is surprisingly close to later more detailed calculations.

A regression analysis was also performed on the tape power data. It showed the building's strongest power fluctuations were due to temperature and gave a figure of 90 KW/°F as the correlation factor.

Both of the temperature correlation factors gained by these two analyses do not provide information as to why the power demand increases as it does, how much heat is lost through convection. They merely point out the total variation.

This analysis substantiated the initial assumption that environmental services were consuming the most energy, and they furthermore pointed out heating as a major portion of these services; heating alone would consume 40% of the annual energy in as average year. Enough information was now available to rank the major energy consumers.

3-V Ranking the Major Energy Consumers

Table 3.2 is a listing of the breakdown of major energy consumers according to the percentage of the annual energy bill they share. Figure 3.3 is a graphical presentation of Table 3.2. Appendix B is a detailed accounting of the ranking procedure. As was assumed, environmental services consumed the largest portion of the annual bill with 73.1 percent. Production support consumed only 26.9 percent of the annual energy. The environmental services area still is the prime area to start a conservation program.

3-VI Analysis of Building Heat Loss

Since the major portion of the conservation program will be aimed at reducing heating and cooling energy, a detailed study of the heat loss of the building was conducted. Appendix C contains this study which was based on the formulas of section 2-VI. The study closely supports the preliminary investigation heat load correlation factors with a figure of 1551 KWHR's/degree day or 106 KW/^oF. An important fact that this study did bring to light was the magnitude of heating and cooling required for the ventilation air. This convection heat loss was three times as large as the conduction heat loss, 1930 KWHR's/degree day for ventilation heat loss and 621 KWHR's/degree day for conduction loss. Reducing air change rate of conditioned air was now a major objective of the conservation program.

3-VIII Formulating Energy Conservation Programs and Estimating Savings

It is obvious from Table 3.2 that any conservation program should try to first reduce heating and cooling energy consumption. The thermodynamic analysis of the building points out the heating of ventilation air as the largest consumer. There are then several things that can be done to conserve energy and reducing heating, cooling, lighting and ventilation should top the list.

Guidelines in Chapter 2 should now be applied to these primary energy users to establish the conservation program. In the heating season, the inside temperature of the plant must be lowered to a universal 68°F as suggested by the Federal Energy Office. The rate of air change must be reduced to absolute minimums. During times that the plant is not occupied, the ventilation blowers must be secured. When the plant is occupied, the ventilation should be operated only when actually needed. In the winter, the perimeter heating units in the administrative building must be secured so that temperature can be controlled at only a few points by authorized personnel.

In the summer, ventilation rates must also be reduced and the plant inside temperature raised to at least 78 to 80°F.

Light levels should be reduced to recommended levels year round and turned off during the hours the building is unoccupied.

It was also noted during the preliminary plant investigation that the air conditioners were not being turned off during the heating season. If the controls of the heating and cooling units were

not syncronized properly, it is possible for both types of units to be operating at the same time. Since each unit handles 49,000 CFM, it is possible for two adjacent units with a $1^{o}F$ overlap in thermostat setting to use an unnecessary 23.7 KW to maintain the average unit temperature. If this is continued for a 215 day heating season, it could waste 120,000 KWHR's of electricity. This is almost 2.0 percent of the annual energy consumption. If the overlap were increased to all units and expanded to 2 ^{o}F, it would waste nearly 5 percent per year. It was suggested that all air conditioners be turned off during the heating season.

Appendix D contains an estimation of the savings to be expected from the conservation program. The estimating conservation program was:

Winter: Lower inside plant temperature 10 ^{o}F
Turn off exhaust blowers 12 hours of the day for an air change rate of 0.5. Only start blowers each day when actually needed for an air change rate of 0.75 for four hours.
Leave exhaust rate at normal 1.0 per hour for the remaining 8 hours each day.

Summer: Turn of 75% of lights 8 hours a day.
Raise inside temperature 6 ^{o}F to 78 ^{o}F

These programs yielded a 24.8 percent annual savings. Heating saved 12.0 percent. Ventilation reduction saved 7.6 percent. Lighting reduction saved 3.4 percent by reducing cooling requirements, and

temperature raising in the summer saved 1.8 percent.

Ventilation saving was based on lowering the average daily air change rate only 25 percent. It is felt that this is conservative. The air change saving was also based on average daily temperature difference. In actuality, most ventilation reduction will take palce at night when ΔT is larger than the daily average. This also makes the estimation conservative. The above was the conservation program as it was used to estimate savings based on the calculations of Appendix D. Table 3.3 shows the actual conservation program as publicized at the plant.

3-IX Establishing a Control Week

To have a control against which the effectiveness of the conservation program may be judged, one must know how much energy was being consumed, under what conditions, prior to program implementation. For this reason, a week was set aside prior to program implementation when plant power consumption, internal temperature, external temperature, and plant daily work force level were recorded. These recordings would be the bench mark against which power consumption comparisons would be made. This was done for the week of October 31 to November 6, 1973 and the results are contained in Appendix E.

Table 3.1

Plant Characteristics - Raytheon West Andover Plant

I. Building - General Information

Two connected buildings

Administrative building - 3 floors, 50% glass walls

Manufacturing building - 1 floor, 20% glass walls

Ground floor area - 600,000 ft^2

Total glass area - 30,000 ft^2

Total wall area - 80,000 ft^2

building volume - 15,000,000 ft^3

II. Energy Sources

Total electric

III. Product

Electronics Components and Hawk Missiles

IV. Heating, Ventilation and Air Conditioning

A. Heating (Electrical Resistance Coils)

(i) 218 Administration building 1 KW units - 218 KW

(ii) Administration blast coils - 3612 KW

(iii) Assembly building 24 rooftop units - 7440 KW

Total Heating Capacity - 11,270 Kw or 38.46×10^6 BTU/Hr

B. Cooling

(i) 218 Administration Building Units

75% with 1 ton and 25% with 1.5 tons - 290 tons

(ii) Administration building chillers - 715 tons

(iii) Assembly building 24 rooftop units - 3,120 tons

Total Cooling Capacity - 4125 tons or 49.5×10^6 Btu/Hr

C. Ventilation

250,000 CFM of installed exhaust in assembly building equaling 1.0 air changes per hour.

D. Lighting

1600 KW or 2.7 Watts/Ft^2

A RANKING OF MAJOR ENERGY CONSUMERS

Energy Consumer	Percentage of Annual Energy
Heating:	
From heating units	25.6
From lights in heating season	13.7
From manufacturing machines	11.2
Total	50.5
Cooling	
Cooling light heat in cooling season	4.8
Cooling machinery heat	3.9
Cooling heat from outside building (Weather)	1.7
Total	10.4
Lighting:	
Lights, not included in heating	12.2
Manufacturing:	
Manufacturing not included in heating	26.9

Table 3.2

Table 3.3

Energy Conservation Program (Winter Plant)

I. Reduction of Heating

A. Reduce building heat to 68 F

B. Turn off 6 of the 9 ton air conditioning chillers on the Administrative building

C. Turn off 90 of the 96 air conditioning compressors on the Assembly building.

D. Turn off all exhaust fans at night and when not in use.

II. Reduction of Lighting

A. All East - West aisle lighting will be reduced to one third of original level.

B. All lights in the Administrative building will be turned off at 8:30 pm. daily, excluding the Computer Area.

C. Lighting in the Assembly building will be shut off according to a block diagram.

D. All outside lights will be turned off permanently.

E. All parking lot lights will be turned off on weekends.

F. All bench lighting and dazor lamps will be turned off when not in use.

Table 3.3 (cont).

G. During working hours, cafeteria lights will be reduced to every other fixture and all lights will be turned of at 8:30 pm.

H. Lights in the Main Reception room will be reduced by 50%.

I. Light levels in all office areas will be reduced to 2 tubes in every 4 tube fixtures.

III. Miscellaneous

A. All tpyewriters and calculators will be turned off when not in use.

B. All electrical equipment such as ovens and grill will be turned off when not in use.

Figure 3.1, B

8 August 1972 (Summer)

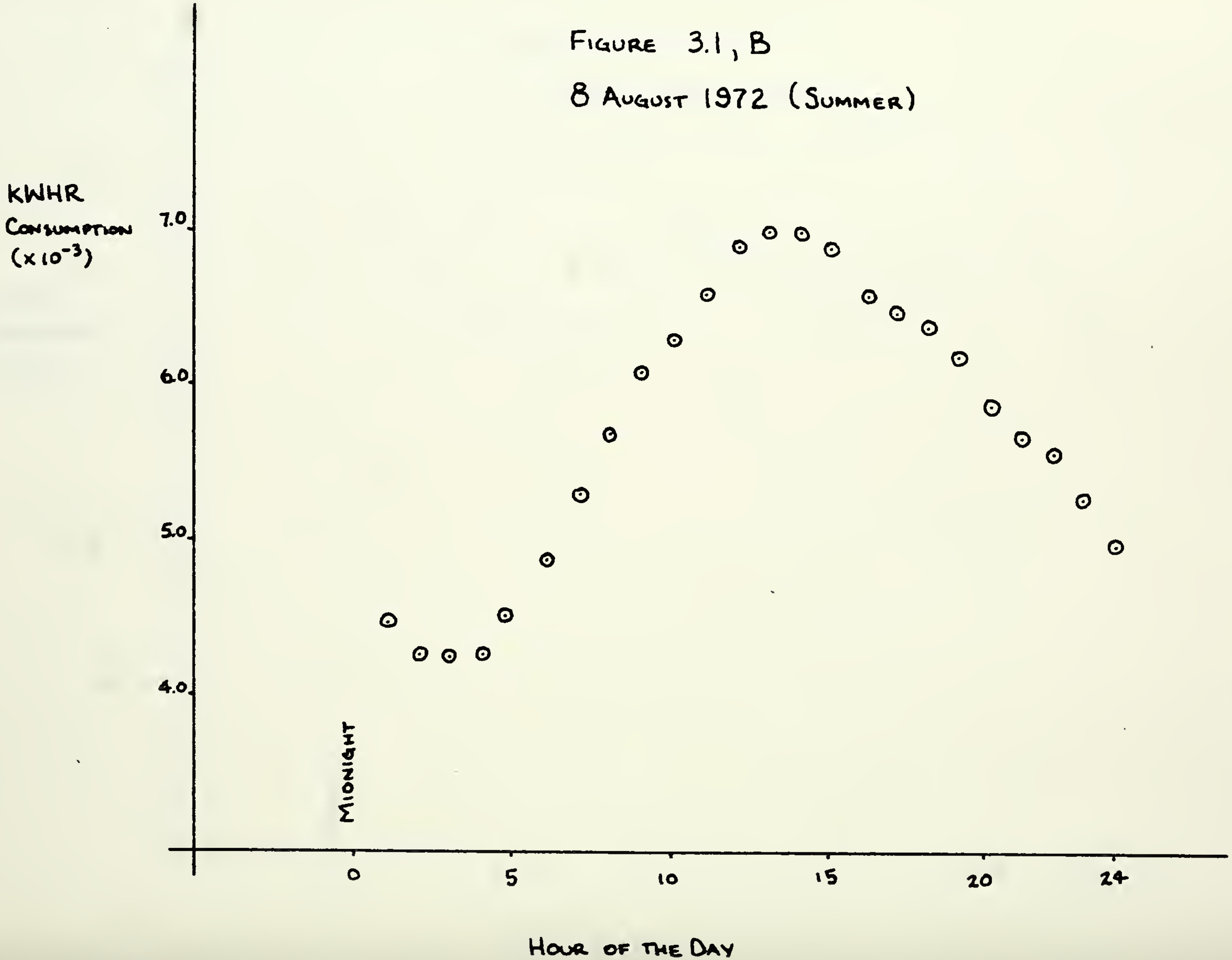


FIGURE 3.1, A

1 JANUARY 1972 (WINTER)

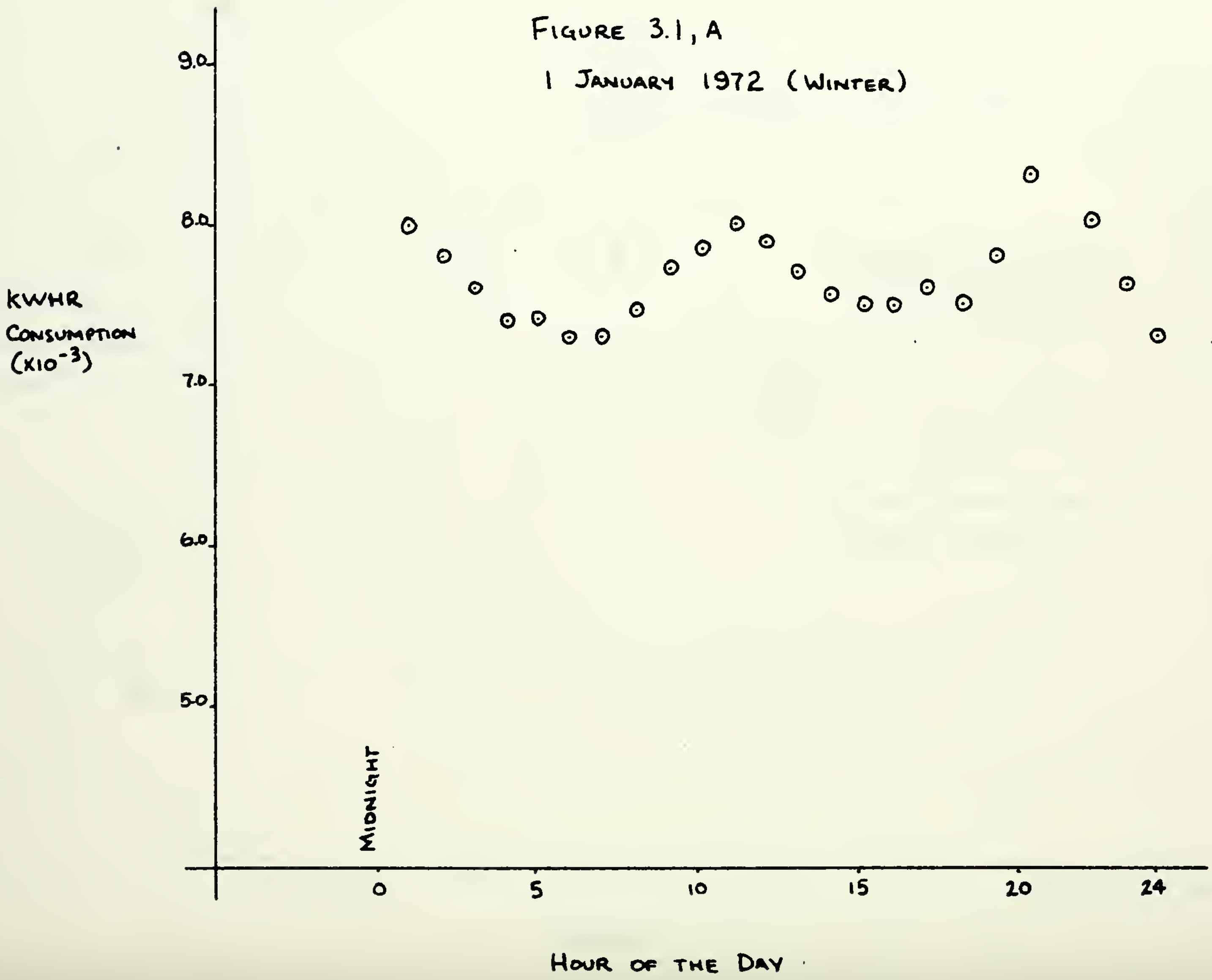


Figure 3.2

Monthly KWHR Consumption

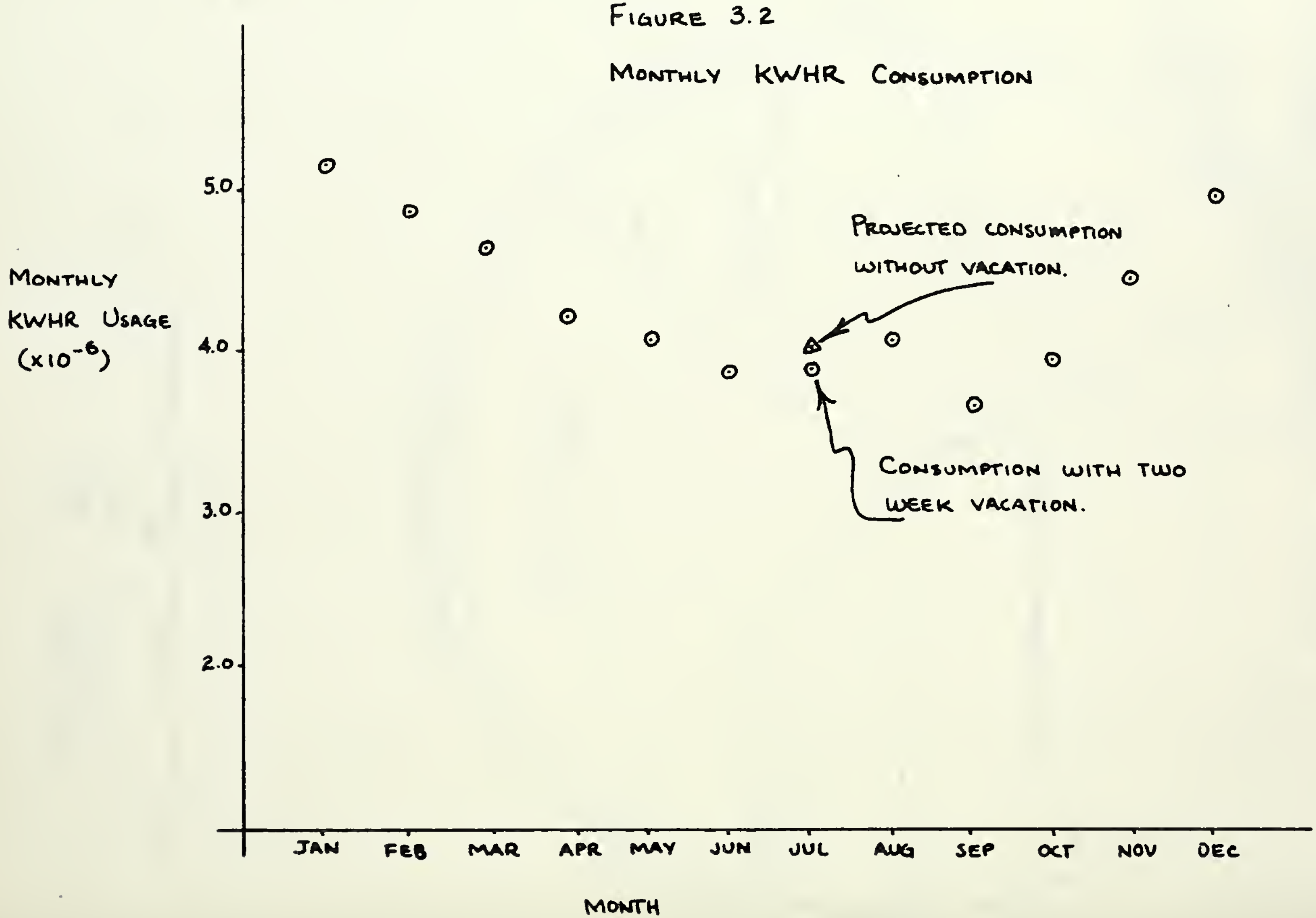
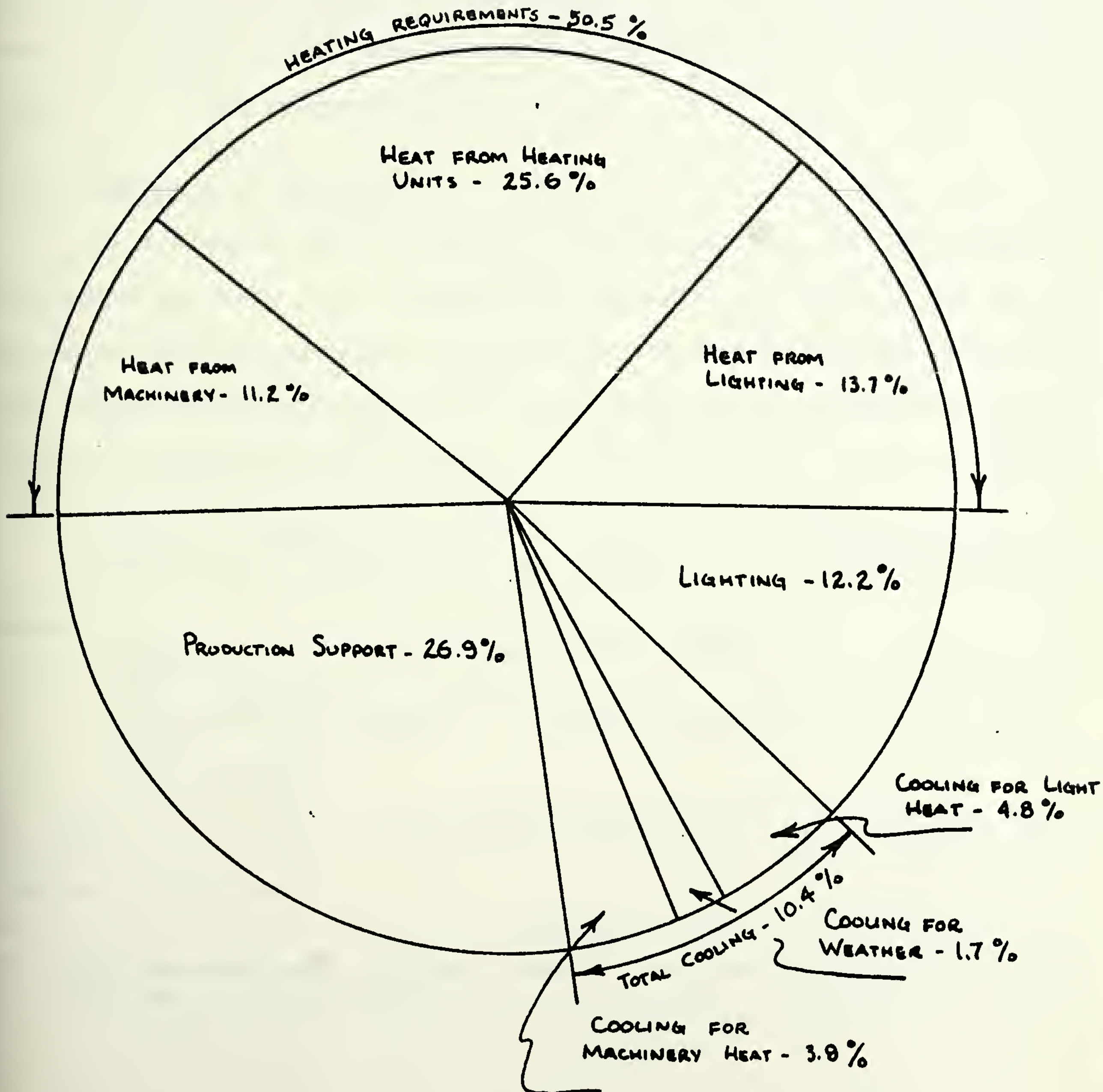


FIGURE 3.3

RANKING OF MAJOR ENERGY CONSUMERS



IV

CONSERVATION PROGRAM RESULTS

4-1 Program Implementation

After all the preparatory steps outlines in Chapter 3 were taken, the conservation program was implemented on November 9, 1973. The recording devices used to record information for the control week were also used to continuously record the data needed for the evaluation of program results.

4-II Evaluation Procedures

To evaluate the savings on a particular day, the following procedure was used. This procedure corrects the control day to the same outside temperature conditions as the day under consideration and calculates total savings by subtracting hourly KW requirements from corresponding control day requirements. As an example:

$$KW_{savings} = \text{Abs.} \left| KW_{test\ day} - KW_{control\ day} \begin{array}{l}\text{(corrected for}\\ \text{outside temperature)*}\end{array} \right|$$

where

$$KW_{control\ day}\ \text{(corrected for temperature)} = KW_{control\ day} - \text{(Outside temperature} - \text{Outside temperature control day)} \times 90\ KW/^{o}F$$

$90\ KW/^{o}F$ is the heat loss factor obtained from the electrical data regression analysis.

---

* This temperature should be taken at the same frequency as the KW Readings, usually hourly.

This KW savings can be broken down into three parts. The savings due to thermostat lowering, the savings due to air change reduction, and miscellaneous savings.

4-II-A Heat Saving

Heat savings is simply the building heat loss factor (90 KW/^{O}F) multiplied times the difference in inside temperature between the control day and the test day. This heat includes that required for both conduction and convection (ventilation) heat loss.

4-II-B Air Change Saving

Air change saving represents the reduction in heating requirements due to a reduction of ventilation rates. These savings are more difficult to estimate than heat savings. There are no timers on the exhaust blowers so an estimate must be made of how the building air change rate changes with varying numbers of exhaust blowers operating. Then an estimate of what exhaust blowers are operating during each hour of the day must be made.

In this particular case it was presumed that the air change heat load was reduced by $^{1}/3$ for 12 hours of the day, form 1900 to 0600, and by $^{1}/6$ for 4 hours, from 0700 to 1000. This reduction corresponds to 75 percent of the exhaust blowers being turned off for the $^{1}/3$ reduction in air change rate and with half of the secured blowers being turned on during the $^{1}/6$ reduction period. The remaining 8 hours continued at the normal air change rate of one per hour.

Ventilation rate change is also made difficult to estimate by

the fact that exhaust blowers are not controlled at any central location. One must rely on a number of individual workers to consistently turn off their particular blower at the same time each day.

4-II-C Miscellaneous Savings

Miscellaneous savings are all those savings not accounted for by heating or air change reduction. They result from many things. Some come from a general tightening up of operating procedures that don't change environmental conditions but cause the plant to operate more efficiently. As an example, air conditioners were turned off at the beginning of the program. In past years, the thermostats were relied on to keep the air conditioners from running, but it was entirely possible for an air conditioner in one zone to be operating while a heater in an adjacent zone was over heating. As was pointed out in Chapter 3, this could result in a considerable waste of energy.

Lighting reduction could also represent some of this miscellaneous savings. This is the winter season and lighting reduction will cause a loss in some of the building heat gain, but this will be picked up by the buildings heaters, which are a more efficient source of heat.

Some of the miscellaneous savings must also be attributed to worker attitude. Everyone in the plant was fully aware of the conservation program and certainly did what they could in their own work area to conserve. This saving is unreported and shows up in the miscellaneous category.

4-III Program Results

Table 4.1 lists 15 days of the conservation program with accompanying total savings. As one can see, the savings range from 11.4 percent to 21.7 percent with an average of 15.6 percent. Some observations from the table follow:

(1) When the program began, the middle of November, savings were large. On 16 November, the average inside temperature was 68 °F compared with 77 °F on a corresponding control day. This alone resulted in 19,440 KWHR savings for the day. The exhaust blowers were not turned off on the 16th, so savings were heat savings and miscellaneous savings only. On following days, the temperature of the plant began to creep back to its pre-conservation level, i.e. November 16, average temperature 68 °F, December 4, average temperature 71 °F, January 9, average temperature 74 °F.

(2) On weekends, notably December 1 and 2, savings were larger than on weekdays, because the number of weekend workers was cut to a minimum, and exhaust blowers were turned off.

(3) December 4 and 5 were two days when exhaust blowers were monitored closely. Both of these days showed increased savings, which was the result of reducing ventilation rates. December 4 saving was greater than December 5, due to the lower inside temperature on December 4.

(4) January 8 and 9 both illustrate the fall off of savings from the beginning of the project. The average saving in November and December was 15.8%. The two days in January showed a 14.1%

saving. As the average outside temperaure gets lower, the savings should increase slightly, as illustrated by Table 4.4. The savings on January 8 and 9 were not as large as savings realized on some warmer days in December.

4-IV Detail of Daily Savings

Table 4.2 is a detail of the daily savings for December 4 and 5 and January 8 and 9. Table 4.3 shows the hourly energy consumption, and inside and outside temperature for the days in question as well as for the comparison days.

December 4 and 5 were days when the exhaust blower status was known. From this information, an estimation of air change rate ventilation was made. The savings for this ventilation reduction is shown in Table 4.2 and 4.3.

January 8 and 9 were days when the exhaust blower status was not known. The air change savings have not been separated from the miscellaneous savings. There were air change savings on these days but it is felt that they are not as large as on December 4 and 5.

TABLE 4.1

Summary of Fifteen Days of Conservaion Program

Date	Total KWHR Use	Total KWHR Savings	%	Average Temp (°F)
11/16/73	153,730	30,050	19.5	40
11/17/73	142,810	23,430	16.4	38
11/18/73	111,560	14,730	13.2	43
11/19/73	148,030	16,890	11.4	39
11/20/73	167,020	19,070	11.4	34
11/27/73	148,840	19,050	12.8	43
11/28/73	142,460	25,230	17.7	45
11/29/73	138,630	21,640	15.6	43
12/ 1/73	155,350	30,570	19.7	33
12/ 2/73	147,760	32,080	21.7	31
12/ 3/73	139,730	17,960	12.9	39
12/ 4/73	148,930	29,320	19.7	47
12/ 5/73	128,770	17,200	13.4	58
1/ 8/74	195,910	31,760	16.2	21
1/ 9/74	211,630	25,420	12.0	17

TABLE 4.2

Detail of Daily Savings

I. 4 December 1973

Actual Energy Used:	1.19613×10^5 KWHR	
Total Energy Saved:	0.29315×10^5 KWHR	
*Sum :	1.43928×10^5 KWHR	
	KWHR	%
Heat Savings :	12,960.0	8.7
Air Change Savings :	10,285.0	6.9
Miscellaneous Savings:	6,070.0	4.1
Total		19.7

Average Inside Temp : 71.00°F

Average Outside Temp. : 44.04°F

Average Outside Temp. During Period of Exhuast Blower Shutdown : 40.90°F

Note: Sum is equal to the energy that would have been used without conservation.

II. 5 December 1973

Actual Energy Used:	1.11563×10^5 KWHR
Total Energy Saved:	0.17202×10^5 KWHR
Sum :	1.28765×10^5 KWHR

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* This is the amount of energy that would have been used without conservation.

	KWHR	%
Heat Savings :	3,330.0	2.6
Air Change Savings :	8,625.5	6.4
Miscellaneous Savings:	5,610.0	4.4
Total		13.4

Average Inside Temp :	73.20 °F
Average Outside Temp :	51.29 °F
Average Outside Temp. During Period of Exhaust Blower Shutdown:	50.25 °F

III. <u>8 January 1974</u>

Actual Energy Used: 1.64150×10^5 KWHR

Total Energy Saved: 0.31758×10^5 KWHR

Sum : 1.95908×10^5 KWHR

	KWHR	%
Heat Savings :	15,300.0	7.8
Air Change Savings :	Unknown	-
Miscellaneous Savings:	16,457.5	8.4
Total		16.2

Average Inside Temp :	69.9 °F
Average Outside Temp:	22.3 °F

(cont. overleaf)

Table 4.2 (Cont.)

IV. 9 January 1974

Actual Energy Used:	1.85613×10^5 KWHR	
Total Energy Saved:	0.25415×10^5 KWHR	
Sum :	2.11028×10^5 KWHR	

	KWHR	%
Heat Savings :	5,580.0	2.6
Air Change Savings :	Unknown	-
Miscellaneous Savings:	19,820.0	9.4
Total		12.0

Average Inside Temp :	74.4 °F
Average Outside Temp.:	15.3 °F

TABLE 4.3, A

Test Day: 4 December 1973

	TEST DAY			CONTROL DAY*					
Hour	KWHR	Inside Temp	Outside Temp.	KWHR	Inside Temp	Outside Temp.	Heat Savings	Air Change Savings	Miscellaneous Savings
1	4712.5	70	36	5917.5	76	37	525	850	-25.0
2	5525.0	69	36	6150.0	75	36	525	825	360.0
3	4212.5	68	37	6137.5	75	36	630	775	430.0
4	4100.0	67	38	6187.5	75	35	720	725	370.0
5	4150.0	67	37	6137.5	75	35	720	750	340.0
6	4262.5	67	38	6200.0	75	34	720	725	135.0
7	4562.5	67	38	6550.0	76	33	810	365	365.0
8	5525.0	68	39	7137.5	77	35	810	365	130.0
9	6062.5	70	41	7687.5	77	38	630	365	360.0
10	5925.0	71	42	7437.5	77	40	525	365	340.0
11	5825.0	72	43	7062.5	77	41	450	0	605.0
12	5687.5	72	45	7000.0	77	42	450	0	590.0
13	5675.0	73	49	6812.5	78	42	450	0	60.0
14	5837.5	73	53	6900.0	78	42	450	0	-375.0
15	5775.0	74	54	6862.5	78	42	360	0	-350.0
16	5475.0	74	55	6800.0	78	41	360	0	-295.0
17	5100.0	73	54	6775.0	78	40	450	0	-35.0
18	4750.0	73	52	6912.5	78	39	450	0	545.0
19	4625.0	72	49	7112.5	78	38	525	575	385.0
20	4612.5	73	47	7137.5	78	37	525	625	460.0
21	4737.5	73	45	7100.0	78	36	450	700	405.0
22	4625.0	73	44	6700.0	78	37	450	725	270.0
23	4500.0	73	43	6612.5	78	38	450	750	465.0
24	4450.0	73	41	6437.5	78	38	450	800	465.0

* Coldest Control Day

TABLE 4.3, B

Test Day: 5 December 1973

	TEST DAY			CONTROL DAY*					
Hour	KWHR	Inside Temp	Outside Temp.	KWHR	Inside Temp.	Outside Temp.	Heat Savings	Air Change Savings	Miscellaneous Savings
1	4725.0	73	41	4900.0	74	48	90.0	800.0	365.0
2	4125.0	73	42	4787.5	74	49	90.0	775.0	337.5
3	3900.0	74	42	4712.5	74	49	0	800.0	642.5
4	3725.0	74	42	4662.5	75	49	90.0	800.0	677.5
5	3762.5	74	43	4700.0	75	49	90.0	775.0	612.5
6	3712.5	74	44	4725.0	75	50	90.0	750.0	712.5
7	4075.0	73	44	4937.5	75	50	180.0	362.5	860.0
8	4912.5	73	45	5287.5	74	51	90.0	350.0	475.0
9	5537.5	74	47	5875.0	75	52	90.0	337.5	360.0
10	5600.0	72	49	5750.0	75	52	270.0	287.5	-137.5
11	5525.0	72	52	5912.5	76	53	360.0	0	117.5
12	5637.5	72	54	5950.0	76	54	360.0	0	-47.5
13	5462.5	73	55	5850.0	76	54	270.0	0	27.5
14	5512.5	73	56	6212.5	76	52	270.0	0	70.0
15	5375.0	73	56	6075.0	76	52	270.0	0	70.0
16	5187.5	74	57	5887.5	75	52	90.0	0	160.0
17	9962.5	74	57	5850.0	75	51	90.0	0	257.5
18	4700.0	74	56	5612.5	74	49	0	0	282.5
19	4537.5	73	56	5637.5	74	50	90.0	425.0	45.0
20	4337.5	73	57	5600.0	74	50	90.0	400.0	142.5
21	4350.0	73	58	5637.5	74	50	90.0	375.0	102.0
22	4212.5	73	59	5350.0	74	51	90.0	350.0	-22.5
23	4025.0	73	59	5075.0	74	50	90.0	350.0	-200.0
24	4112.5	73	60	5087.5	74	50	90.0	325.0	-340.0

* A Control Day that most nearly matched the test day outside temperatures

TABLE 4.3, C

8 January, 1974

	TEST DAY			CONTROL DAY*					
Hour	KWHR	Inside Temp	Outside Temp.	KWHR	Inside Temp	Outside Temp.	Heat Savings	Air Change Savings	Miscellaneous Savings
1	5650.0	69	28	5987.5	76	37	630	NOT IDENTIFIED	517.5
2	5225.0	68	26	6150.0	75	36	630		1195.0
3	5237.5	67	26	6137.5	75	36	720		1080.0
4	5487.5	67	25	6187.5	75	35	720		880.0
5	5525.0	67	23	6137.5	75	35	720		972.5
6	5825.0	67	22	6200.0	75	34	720		735.0
7	6537.5	68	21	6550.0	76	33	720		372.5
8	6887.5	68	20	7187.5	77	35	810		840.0
9	7700.0	68	20	7687.5	77	38	810		797.5
10	7837.5	68	21	7437.5	77	40	810		500.0
11	7625.0	69	23	7062.5	77	41	720		337.5
12	7400.0	69	25	7000.0	77	42	720		410.0
13	7437.5	69	25	6812.5	78	42	810		95.0
14	7450.0	70	26	6900.0	78	42	720		170.0
15	7312.5	70	26	6862.5	78	42	720		270.0
16	7025.0	70	25	6800.0	78	41	720		495.0
17	6775.0	70	23	6775.0	78	40	720		810.0
18	6450.0	71	21	6912.5	78	39	630		1452.0
19	7137.5	73	20	7112.5	78	38	450		1145.0
20	7275.0	74	20	7137.5	78	37	360		1032.5
21	7587.5	74	19	7100.0	78	36	360		682.5
22	7575.0	74	18	6700.0	78	37	360		475.0
23	7600.0	74	16	6612.5	78	38	360		632.5
24	7587.5	74	15	6437.5	78	38	360		560.0

* Coldest Control Day

TABLE 4.3, D

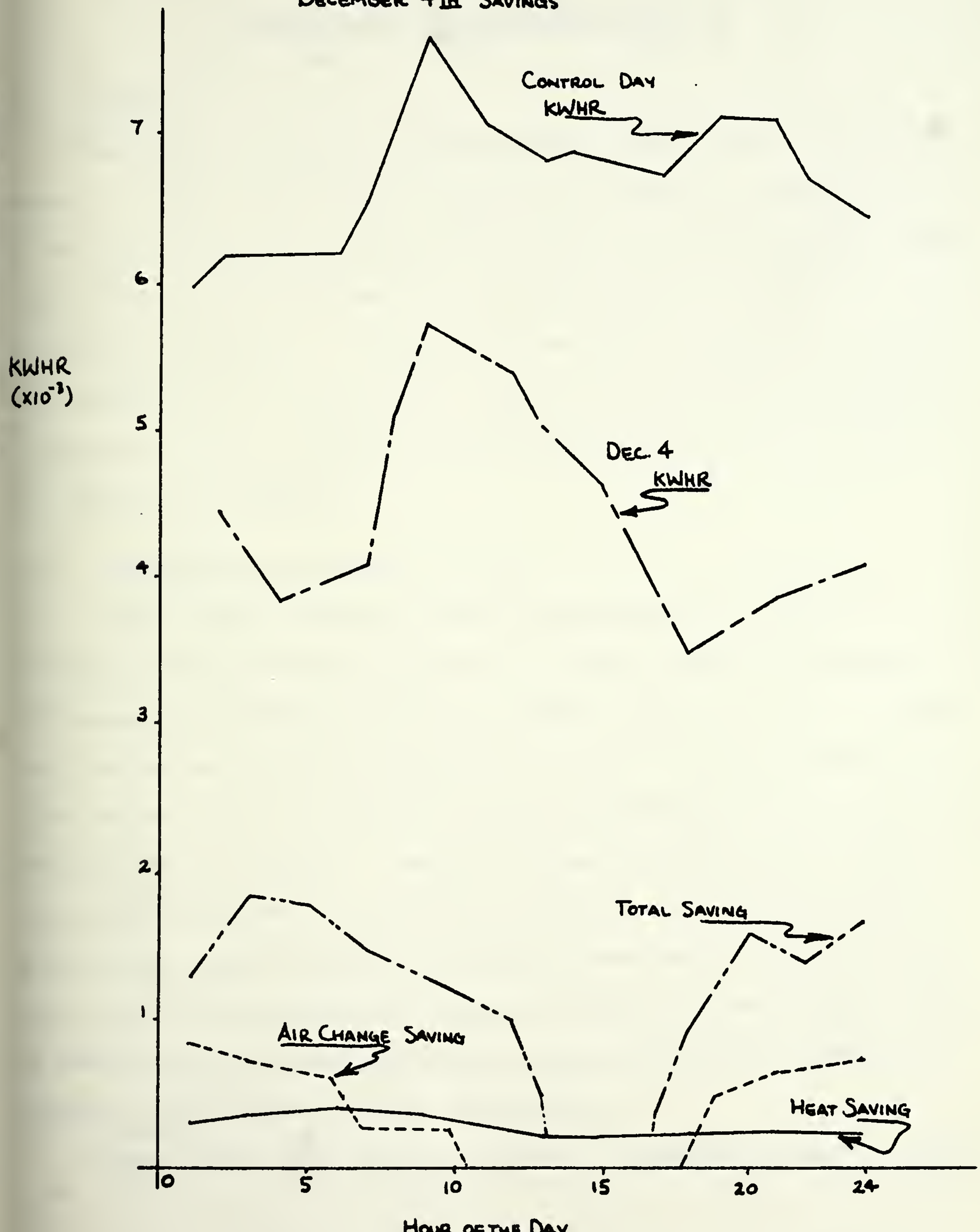
9 January, 1974

	TEST DAY			CONTROL DAY*					
Hour	KWHR	Inside Temp	Outside Temp.	KWHR	Inside Temp	Outside Temp.	Heating Savings	Air Change Savings	Miscellaneous Savings
1	7600.0	73	14	5987.5	76	37	270.0	NOT IDENTIFIED	277.5
2	7212.5	72	14	6150.0	75	36	270.0		647.5
3	7025.0	72	14	6137.5	75	36	770.0		822.5
4	7062.5	72	14	6187.5	75	35	270.0		745.0
5	7162.5	72	14	6137.5	75	34	270.0		595.0
6	7137.5	72	14	6200.0	75	34	270.0		592.5
7	7475.0	73	14	6550.0	76	33	270.0		515.0
8	8087.5	74	12	7187.5	77	35	270.0		900.0
9	8787.5	75	12	7687.5	77	38	180.0		1060.0
10	8850.0	76	12	7437.5	77	40	90.0		1042.5
11	8850.0	76	12	7062.5	77	41	90.0		732.5
12	8725.0	76	13	7000.0	77	42	90.0		795.0
13	8612.5	76	14	6812.5	78	42	180.0		540.0
14	8500.0	76	15	6900.0	78	42	180.0		900.0
15	8450.0	76	17	6862.5	78	42	180.0		482.5
16	8175.0	75	18	6800.0	78	41	270.0		425.0
17	7962.5	75	18	6775.0	78	40	270.0		522.5
18	7612.5	75	18	6912.5	78	39	270.0		920.0
19	6962.5	75	18	7112.5	78	38	270.0		1680.0
20	7087.5	75	18	7137.5	78	37	270.0		1490.0
21	7125.0	75	18	7100.0	78	36	270.0		1325.0
22	7000.0	75	18	6700.0	78	37	270.0		1140.0
23	7112.5	75	18	6612.5	78	38	270.0		1030.0
24	7037.5	75	18	6437.5	78	38	270.0		930.0

*Coldest Control Day

Figure 5.1

December 4th Savings



V

CONCLUSIONS AND RECOMMENDATIONS

5-I General

There are two major conclusions that can be drawn form this report. First, there can be significant amounts of energy, 10 to 20 percent, cut from the annual energy bill of most manufacturing plants without any adverse effect on production of harmful effects on working conditions. Second, the amount of energy saved does not depend only on identifying conservaion areas and establishing programs. It also depends on motivating management and workers to follow the programs.

5-II Significant Savings Possible

This report has dealt with a manufacturing plant in the Northeast, with a major portion of its energy used to maintain environmental conditions. In this particular case, 10 to 20 percent saving has been demonstrated. It can further be said that like saving can be expected from the environmental services energy consumed by all plants. One has to lower the building's inside temperature in winter and reduce ventilation rates. The study showed that these conservaion measures were about equal in importance, with the thermostat lowering saving the same amount of energy each day in the heating season and the ventilation reduction savings varying with outside temperature.

Light levels must also be lowered. Lighting provides a very

inefficient source of heat in the winter and an absolutely undesirable source of heat in the summer. As can be seen from the cooling requirements for the case study plant in Chapter 3, most of the summer cooling was required for removing lighting heat. Any conservation program aimed at the environmental control system will be a combination of these three things; light level reduction, air change reduction, and temperature differential reduction.

This report has dealt with a plant that was already in existance, so the conservation program consisted of changing operating procedures on existing equipment. In a new building, one would have much more flexibility in tayloring the plant to conserve energy. Some things that reduced the effectiveness of this report's conservation program were the large amounts of single pane glass in the plant, the large amount of ventilation air required in certain areas of the plant, and the lack of centralized controls for such things as exhaust blowers, thermostats, and lights.

The single pane glass has a lower first cost than double pane insulating glazing, but the single pane glass has cost much more over the years in increased heating bills. A new building should have more attention given to insulation with more emphasis placed on possible heating bill reduction and less on first cost. Life cycle should be used as a more important and realistic cost indicator.

In the case of large amounts of air turnover, a new building

could have air change better taylored to exact needs. In the case study building, a majority of buildings had far too much ventilation when the exhaust blowers were operating and not enough when they were not running. The exhaust blowers in a new plant could be sized to exact requirements. Areas that require high air change rates could be separated from low rate areas. Finally, areas that do require a high air change rate could either be supplied with unheated air or have heat exchangers installed on blower outlets. There are heat exchangers available now with efficiencies near 80 percent that could pay for themselves in a new installation by the reduced heating and cooling capacity required.

As an example:

Cooling capacity costs about \$700 per ton (12,000 BTU/Hr) and heating capacity costs about \$75 per 33,000 BTU/Hr. A heat exchanger costs about \$0.66 per CFM of air handling capacity.

For a 45,000 CFM unit; Cooling from 95 ^{o}F to 75 ^{o}F sets maximum cooling requirements and heating for a 80 ^{o}F maximum ΔT x sets maximum heating requirements.

$$\text{Capital Cooling Unit Cost} = (45{,}000 \text{ CFM} \times 60 \text{ Min/Hr} \times 20\ ^{o}\text{F} \times 0.0183 \text{ BTU}/^{o}\text{F-Ft}^3 \times \$700)/12000 \text{ BTU/Ton} = \$57{,}645.00$$

$$\text{Capital Heating Unit Cost} = (45{,}000 \text{ CFM} \times 60 \text{ Min/Hr} \times 80\ ^{o}\text{F} \times 0.0183 \text{ BTU}/^{o}\text{F-Ft}^3 \times \$75)/33{,}000 = \$8{,}983.00$$

Heat Exchanger Cost = 45,000 CFM x $0.66?CFM = $29,700.0

With a heat exchanger efficiency of 80% only 20% of the heating and cooling capacity need be installed with the heat exchanger.

Capital Heating and Cooling Unit Cost with Heat Exchanger

= 0.2 x $66,628.00

= $13,325.000

Therefore the heat exchanger can save,

$66,628.00 - ($29,700.00 + $13,325.00)

= $23,603.00

with its initial installation, not to mention the continuous savings that would result from lower heating and cooling bills. Table 5.1 shows a retrofit heat exchanger example.

Centralized controls would make any conservation program run more smoothly. As I will show later, any program will work better if it is taken out of the hands of many people and given to just a few people. Centralized controls would allow this transfer of authority. Things like light, exhaust blowers, heaters, etc., could be controlled from one or a few locations and could be manipulated by one man on a very regular schedule. This would end the need for continued efforts on the part of a large number of the work force to make the program work.

5-III <u>Motivation of the Work Force and the Company</u>

Motivation is the key to conservaion. The identification of conservation areas and the formulation of conservation programs is a minor project compared to the effort that must go into promoting

the project and motivating all concerned to follow the rules. The motivation for anyone or any company to follow a conservation project must someway be tied to their survival. That survival is the preservation of jobs and the preservation of production. Conservation for conservation's sake will motivate only a very few people.

The rule of survival can be applied to and sustained by this report's case study. Work has begun on this project as a cost reduction program. It became obvious very quickly that large amounts of money could be saved by energy conservation, but this large amount of money, nearly $250,000 **annually**, was only a small percentage of the plant's total operating overhead, less than 1%. The effort required to follow the program and the minor discomfort that would be given the workers, more than offset the monetary savings that the program could provide. The program was not instituted. Conservation for conservations sake would not motivate the plant to save, neither would the small amount saved, on a relative scale.

In November 1973 when oil shortages and the oil boycott came into effect, there was a dramatic shift in company and worker interest in a conservation program. There was an opinion shared by all in the plant that if conservation measures were not taken, production would be cut by a shortage of electrical power, and jobs would be lost. Great effort was then put into formalizing, publicizing, and implementing the conservation program. The initial

initial goal was a 10% reduction in energy consumption.

The 10 percent was realized almost immediately and in fact almost twice that amount was being saved consistently. With this steady saving of energy and the mid-winter shift of concern from short supplies of residual oil to concern for gasoline supplies, motivation and interest in the conservation program began to wane. Temperature in the plant began to creep back to pre-conservation levels, exhaust blowers were not being turned off at night with regularity, and the savings that were predicted to go up slightly as the weather got colder, did not show any increase. In fact, savings went down. The crisis had past and production slow-down with accompaning job payoffs was no longer a possibility. The motivation to rigidly adhere to the program was gone.

5-IV <u>Automation as a solution to Conservation Program Problems</u>

Automation of the plant environmental systems would solve a large number of the problems that present themselves in a conservation program. Automation would take all functions out of the hands of humans and ensure that repetative functions were performed regularly and on time. Automation requires no motivation to turn off the lights every night. The only motivation problem associated with this sort of system would be the one connected with convincing management to install the equipment.

A mini-computer which would cost as little as $100,000 could do the job required in any environmental system automation project and it would have enough capacity left over to do other things

associated with production automation. This could be the key to motivating the installation of the automatic system. The computer could also save enough in a plant with a $1,000,000 energy bill to pay for itself in less than a year.

5-V Summary

In summary, this report has shown that saving energy is possible in all manufacturing plants. It has given a general method that can be used to formulate a conservation program and has presented the results of one application of the approach. The report has also brought out the fact that motivation is also a major problem in any conservation program. Any person who undertakes a conservation program must understand what motivates the participants in the program and use this motivation to make his program a success.

TABLE 5.1

Example of Saving by Installing a Heat Exchanger on an Existing Building

Air Flow Rate	:	4500 CFM
Heat Exchanger Efficiency	:	80%
Heating Season Degree Days	:	8000 (to 75 ^{o}F)
Cooling Season Degree Days	:	600 (to 75 ^{o}F)

Heating Required is:

$$45{,}000 \text{ Ft}^3/\text{Min} \times 60 \text{ Min/Hr} \times 0.0183 \text{ BTU/Ft}^3 \, {}^{o}\text{F}$$

$$\times \frac{1}{3413} \frac{\text{KW}}{\text{BTU}} \times 8000 \text{ Degree Days} \times 24 \text{ Hr/Day}$$

$$= 2{,}779{,}583.7 \quad \text{KWHR}$$

Cooling Required is:

$$45{,}000 \text{ Ft}^3/\text{Min} \times 60 \text{ Min/Hr} \times 0.0183 \text{ BTU/Ft}^3 \, {}^{o}\text{F}$$

$$\times \frac{1}{3413} \frac{\text{KW}}{\text{BTU}} \times 600 \text{ Degree Days} \times 24 \text{ Hr/Day} \times 0.5$$

$$= 104{,}234.4 \quad \text{KWHR}$$

Total Heating and Cooling Required is:

2,883,818.0 KWHR

TABLE 5.1-2

KWHR's Saved by Heat Exchanger is:

0.2 x 2,883,818.0 = 576,763.6 KWHR

Heat Exchanger Cost is:

45,000 CFM x $0.66/CFM = $29,700.00

Approximate Cost of Electricity is:

$0.02/KWHR

Total Money Saved is:

$0.02 x 576,763.6 KWHR ≅ $11,540.00

Payback is:

$$\frac{29,700}{11,540} = 2.6 \text{ years}$$

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APPENDIX A

Energy Conservation Information Questionnaire

I. Energy Use Information:

1. What are/is your major source of purchased energy?

    Electricity ______

    Gas ______

    Oil ______, Type ______

    Steam ______

    Coal ______

2. What is your annual use of each?

3. Is billing information and rate schedule information available for each?

4. Who are the suppliers of each?

5. Does your plant produce any warm water effluents?

6. Do you have any large cooling towers or cooling ponds?

7. Do you have electrical demand meters and recorders installed? How much historical data do you hold?

II. Work Force Information:

1. What is the size of your work force?

2. What is the growth history of your work force?

3. How does your work force break down according to blue-collar and whitecollar classification?

4. How does your work force breakdown according to shift?

5. What are the hours of your shifts? (white collar and blue collar)

6. Does your work force commute largely by auto?

7. Do you provide parking facilities?

8. Are you near mass transit terminals?

9. Are your personnel records computerized?

10. Do you have in-plant cafeteria facilities?

III. Product Information:

1. What product or products do you manufacture?

2. How do you charaterize your manufacturing process? i.e. assembly line, piece work, job shop, etc.

3. Do you have a large amount of machinery involved in your manufacturing process?
4. Does your manufacturing process require a large amount of heat?
5. Do you have a large amount of in-plant production transportation requiring tractors, etc?
6. Do you have any known large energy users associated with the manufacturing process?

IV. Physical Plant Information:

1. General:
   A. How many buildings compose your complex?
   B. How old are these buildings (individually)?
   C. How are they heated?
   D. How are they cooled, if the are cooled?
   E. What is your general lighting level?
   F. What type of light sources provides this light?
2. Heating:

   Describe in detail your heating system. Include information such as, source of heat, method of distribution, method of control, amount of fresh air make-up, and name plate data.

3. Cooling:

Describe in detail your cooling system.

4. Exhaust:

A. How much exhaust capacity is installed in your facility?

B. Is this exhaust in isolated areas of the plant, or is it evenly distributed throughout the plant?

C. Do you have any exhaust air heat recovery devices installed?

D. List in detail:

(i) Each exhaust penetration.

(ii) Size of each exhaust.

(iii) Purpose of exhaust.

E. How do you characterize your plant in terms of its air tight integrity?

(i) Tight

(ii) Some leakage

(iii) Moderate leakage

(iv) Leaks like a sieve

F. Are you operating under any regulations that require a minimum number of air changes per hour?

5. Building Heat Transfer properties:

   A. Do you have building heat gain studies available?

   B. What are the dimensions of your plant? (all buildings)

   C. What are the "U" values for the various walls, ceilings etc., if available? If not, what is the make-up of the walls, ceilings, etc?

   D. How much glass is installed in the plant? What is its "U" value?

6. Building Miscellaneous:

   A. Are you manufacturing processes segregated according to heating, cooling, and ventilation requirements?

   B. Do you have any special "clean" areas?

   C. Who maintains your H.V.A.C. equipment?

   D. Do you have a planned preventive maintenance system?

   E. Are there any special plant characteristics that should be pointed out?

F. Do you have any large oil or gas fired boilers?

IV. Conservation to Date:

1. Do you have a plant-wide conservation program in action at present?
2. Do you have a plant conservation "action" committee formed?
3. How do you publicize present and future conservation programs?
4. What have you done to-date to conserve energy?

5. Is there now or can there be a person assigned full time to the conservation problem?

V. Energy Consumption Information:

What is the breakdown of your energy usage?

A. Electrical

1. Air movers
2. Exhaust
3. Lights
4. Air-conditioning
5. Electric motors (detail)
6. Space & water heating
7. Other (detail)

B. Gas

1. Steam generation

2. Space heating

3. Water heating

APPENDIX B

Ranking of Energy Consumers

I Sample Year:

215 Day Heating Season

261 Manufacturing Days

8000 Degree Days (to 75 ^{o}F)

695 Cooling Degree Days (to 75 ^{o}F)

II Assumptions:

A. Daily Year Around Base Excluding Lighting is 1900 KW

B. Daily Manufacturing Load is 1500KW for 10 Hours a Manufacturing Day

C. 90% of Light goes to Heat

D. 50% of Manufacturing Load and Daily Base goes to Heat

E. Heating Factor is 2580 KWHR/DD

F. Cooling Factor is 1290 KWHR/DD

G. Air Conditioning uses 0.5 KW to remove 1.0 KW of Heat.

III Calculations:

A. Annual Heating (All Sources)

8000 Degree Days . 2580 KWHR/deg.day

= 20,640,000 KWR

B. Lighting

(1) Light to Heat in Winter

215 x 1600 KW x 0.9 x 24 Hr

= 7,430,400 KWHR

Winter Light not going to Heat

$$\frac{7,430,400}{0.9} \times 0.1 = 825,600.0 \text{ KWHR}$$

(ii) Light Used in Cooling Season

150 · 1600 · KW · 24 Hr = 5,760 000 KWHR

(iii) Light Caused Cooling

5,760,000 · 0.9 ·0.5 = 2,542,000 KWHR

B. Daily Base KW

(i) Base to Heat in Winter

215 · 1900 KW · 24 Hr 0.5

= 4,902,000 KWHR

(ii) Base not going to Heat

4,902,000 KWHR

(iii) Base used in Cooling Season

150 · 1900 KW · 24 Hr = 6,840,000 KWHR

(iv) Base Caused Cooling

6,840,000 · 0.5 · 0.5 = 1,710,000 KWHR

C. Manufacturing KW

(i) Manufacturing KW to Useful Heat

$$\frac{215}{365} \cdot 261 \cdot 1500 \text{ KW} \cdot 10 \text{ HR} \cdot 0.5$$

= 1,153,050 KWHR

(ii) Manufacturing not going to Heat

1,153,050 KWHR

(iii) Manufacturing used in Cooling Season

$$\frac{150}{365} \cdot 261 \cdot 1500 \text{ KW} \cdot 10 \text{ Hr.}$$

$= 402,230$ KWHR

D. Cooling

(i) Weather Cooling

695 Deg Day · 1290 KWHR/Deg. Day

$= 896,550$ KWHR

(ii) Light Cooling

2,592,000 KWHR

(iii) Base Cooling

1,710,000 KWHR

(iv) Manufacturing Cooling

402,230

Total Cooling = 5,600,780 KWHR

IV Breakdown:

	KWHR	%
A. Heat:		
From Heating Units	13,841,550	25.6
From Lights	7,430,400	13.7
From Machinery	6,055,050	11.2
B. Cooling:		
For Lights	2,595,000	4.8
For Machinery	2,112,230	3.9
For Weather	896,550	1.7

C. Cooling:

Lights (Not to heat)	6,585,600	12.2
Machinery (Not to heat)	14,503,950	26.9
Total	54,017,330	

APPENDIX C

Heat Loss Calculations

Assuming that heat is lost from the plant in two ways, by conduction through walls, floor edges, etc., and by **exhausting** heated air, what is the magnitude of this loss? This appendix examines, through elementary heat transfer calculations, the size of these losses and where they occur.

The basic heat transfer equation applied is:

$$Q = \varepsilon\ U\ A\ \Delta T$$

where:

- Q = Heat transfer per unit time (BTU/HR)
- U = Heat transfer coefficient (BTU/Hr-Ft^2-$^{\circ}$F)
- A = Area of conducting material (Ft^2)
- ΔT = During temperature difference causing the heat transfer

The plant is broken down into areas of like U values and UA values for these areas are calculated. Then the UA values are added to give a total plant condition UA value.

Heat loss through the floor only occurs at the perimeter. The U value for the floor relates only to the linear measure of ground floor perimeter. The UA value for the floor is dimensionally consistent with all other values but it is actually a

$$U\left(\frac{\text{BTU}}{\text{Hr-Ft-}^{\circ}\text{F}}\right) \cdot \text{ Perimeter (Ft)} \quad \text{value.}$$

After an estimation of conduction heat loss, an estimation of convection heat loss (heat carried away by escaping or exhausting air) is made. Air change rate was approximated at one per hour or 250,000 CFM. Since air has a volumetric specific heat of 0.0183 BTU/ft^3 -^{o}F, the energy required to heat ventilation air is:

$$E = 1.0 \text{ Air Change/Hr} \times 0.0183 \text{ BTU/Ft}^3\text{-}^o\text{F} \times 60 \text{ KW/Hr}$$

Total building heat loss is:

$$Q = (\varepsilon UA + E) \cdot \Delta T$$

Calculations:

I Conduction Loss:

U Values : (Supplied by building manufacturer)

Exterior Walls:	0.13 BTU/Hr-Ft^3-^{o}F
Assembly Building Glass:	1.13 BTU/Hr Ft^3-^{o}F
Administration Building Glass:	0.50 BTU/Hr Ft^3-^{o}F
Roof:	0.10 BTU/Hr Ft^3-^{o}F
Floor	0.542 BTU/Hr-Ft-^{o}F

Areas:

Total Roof:	563,064	Ft^2
Floor Perimeter:	3,794	Ft^2
Total Wall:	85,790	Ft^2
Assembly Building Glass:	6,775	Ft^2
Administrative Building Glass:	22,156	Ft^2

UA Values:

Roof:	56,306	BTU/HR-^{o}F
Floor:	2,056	BTU/Hr-^{o}F
Wall:	11,152	BTU/Hr-^{o}F
Assembly Building Glass:	7,656	BTU/Hr-^{o}F
Administrative Building Glass:	11,078	BTU/Hr-^{o}F

Total UA = 88,248 BTU/Hr-^{o}F or 25.9 KW/^{o}F

II Convection Loss:

Air Flow 250,000 Ft^3/min

$$Cp = 0.0183\ BTU/ft^3\text{-}^{o}F$$

$$E = 250{,}000\ Ft^3/min \cdot 60 \cdot min/hr.\ 0.0183\ BTU/ft^3\text{-}^{o}F$$

$$E = 274{,}500\ BTU/hr\text{-}^{o}F$$

or

$$80.4\ KW/^{o}F$$

Total Building Heat Loss Factor

$$= 80.4 + 25.9 = 106.3\ KW/^{o}F$$

APPENDIX D

I Proposed Conservation Program

A. During winter, lower thermostat settings 10 ^oF

B. Reduce air change rate to:

1.0 for 8 hours/day

0.75 for 4 hours/day

0.50 for 12 hours/day

This corresponds to turning exhaust blowers off when the building is unoccupied and only operating blowers when needed when the building is occupied.

Average Air Change Rate is

$$^{12}/_{24} \times 0.5 + {^{8}/_{24}} \times 1.0 + {^{4}/_{24}} \times 0.75 = 0.705$$

C. Turn off 1200 KW of lighting for 8 hours per day year round. This will save a slight amount in winter by shifting heating to the heating units, and it will save a great deal in summer by reducing cooling load.

D. Raise thermostat 6 ^oF in the summer.

II. Saving Estimation

Conduction Heat Loss = 25.9 KW/^oF

Convection Heat Loss = 80.4 KW/^oF

A. Winter thermostat lowering saving

$$10\ ^oF \cdot (25.9\ KW/^oF + 80.4\ KW/^oF) \cdot 24\ Hr/Day$$

$$= 25{,}440\ KWHR/day$$

B. Ventilation Reduction Savings (Winter):

$$80.4 \text{ KW/}^oF\ (1.0 - 0.705) \cdot 24 \text{ Hr/day}$$

$$= 569 \text{ KWHR/}^oF\text{-day}$$

^oF is the inside to outside average days temperature difference

C. Summer

In summer air conditioners use ½ KW to remove 1 KW of heat from the building. Therefore, if heat is conducted into the building at a rate of 106.3 KW/^oF the air conditioners use 53.2 KW/^oF

A. Lighting Reduction:

1200 KW x 8 Hr/day = 9600 KWHR/day

Accompanying Cooling Load Reduction

1200 KW x ½ x 8 Hr/day = 4800 KWHR/day

Total Lighting Saving = 14,400 KWHR/day

B. Raising Thermostat 6 ^oF

$$\text{Savings} = 6\ ^oF \cdot 53 \text{ KW/ F} \cdot 24 \text{ Hr/day}$$

$$= 7632 \text{ KWHR/day}$$

III. Sample Year Energy Usage:

Month	Average ΔT	KWHR/day (x 10^5)	KWHR/mo (x 10^6)
Jan	45	1.65	5.115
Feb	40	1.72	4.816
Mar	36	1.49	4.619
Apr	24	1.40	4.200

(No. III cont.)

May	13*	1.31	4.061
Jun		1.28	3.840
Jul		1.24	3.844
Aug		1.30	4.030
Sep	8*	1.22	3.660
Oct	17	1.28	3.968
Nov	28	1.47	4.410
Dec	38	1.59	4.929
Total			51.492

* For 15 day period of this month

IV. Program Savings:

Month	Heat Savings /day	Air Change savings/day	Light Saving /day	Air Conditioning savings/day
Jan	25,440	25,605		
Feb	25,440	22,760		
Mar	25,440	20,484		
Apr	25,440	13,656		
May	25,440**	7,397**	14,400***	7,632***
Jun			14,400	7,632
Jul			14,400	7,632
Aug			14,400	7,632
Sep	25,400***	4,552***	14,400**	7,632
Oct	25,400	9,673		
Nov	25,400	15,932		
Dec	25,400	21,622		

** First 15 days
*** Last 15 days

Month	Total Savings/Day	Total Savings/Mo (x 10^6)
Jan	51,045	1.582
Feb	48,200	1.350
Mar	45,924	1.424
Apr	39,096	1.173

(No. IV cont.)

May	41,909****	0.629
Jun	22,032	0.683
Jul	22,032	0.661
Aug	22,032	0.683
Sep	52,024****	0.780
Oct	35,113	1.089
Nov	41,372	1.241
Dec	47,062	1.459
Total		12.754

**** 15 days only

V. Percent Savings:

Sample Year's Energy Usage

51,494,000 KWHR

Saved with Programs

12,754,000 KWHR

Percent Saved

= 24.8

APPENDIX E

Establishing a Control Week:

Purpose:- To establish plant environmental, production, personnel, and power consumption conditions during an average operational week in order to have a yardstick against which cutback proposal trials can be measured. The week of Oct. 31 to Nov. 6 1973, will serve as the control week. During this week, no changes in operating conditions will be implemented. All precautions will be taken to insure that production business is conducted as usual. In order to record this operational weeks condition, a record will be kept of outside temperature and relative humidity, manufacturing building temperature and relative humidity, Administrative building second floor temperature and relative humidity, fifteen minute demand meter readings, and daily personnel counts by shift and job breakdown. These records can be compared with similar records that will be kept during the conservation program trial in order to establish program effectiveness.

After the control week conditions have been established and recorded, portions of the cutback proposals can be implemented on a short time basis. Records taken during these trial periods can be compared with the control to update and refine expected program savings.

Control Week: (15 Nov. thru 21 Nov)

Required Items:

(1) Outside Temperature and Relative Humidity

Recorded with 1 week readout. Recorder should be

placed in an open area and not sheltered from wind or sun. Suggestion: Place on grass parking lot divider east of manufacturing building. Note: time clock of outside recorder must be syncronized with inside recorders so that valid comparisons between the two can be made.

(2) Inside Temperatures and Relative Humidity

Recorders (2) at the following locations:

(i) Centrally located in the manufacturing building

(ii) Centrally located on the second floor of the Administrative building

(3) Demand Meter Recording

A weeks fifteen minute demand meter reading will be taken on a tape that will be annotated with start and stop times and dates and removed at the end of the control period. Care should be taken to insure that tape times correspond with temperature recorder times.

Reading:

(4) Personnel

Personnel reading during this week will be assertained through Jack Gallagher after the control week has ended.

(5) Miscellaneous

It is also requested that and major changes in the HVAC system be noted so that their possible effect on the control week can be evaluated.

Control Week 1973 - October 31, (Wed)

Hour	KWHR	Inside Temp.	Outside Temp.
1	4812.5	74	48
2	4700.0	74	48
3	4637.5	74	48
4	4612.5	74	48
5	4625.0	74	48
6	4712.5	74	48
7	4975.0	74	48
8	5387.5	75	48
9	5937.5	75	49
10	6050.0	75	50
11	6012.5	76	53
12	6037.5	76	58
13	6200.0	77	62
14	6187	77	64
15	6312.5	76	64
16	6112.5	76	63
17	5850.0	76	61
18	5475.0	75	58
19	5350.0	74	55
20	5337	74	53
21	5412	75	51
22	5462.5	74	50
23	5037.5	74	50
24			
		74.875	

Control Week 1973 - November 1 (Thurs)

Hour	KWHR	Inside Temp.	Outside Temp.
1	4900.0	74	48
2	4787.5	74	49
3	4712.5	74	49
4	4662.5	75	49
5	4700.0	75	49
6	4725.0	75	50
7	4937.5	75	50
8	5287.5	74	51
9	5875.0	75	52
10	5750.0	75	52
11	5912.5	76	53
12	5950.0	76	54
13	5850.0	76	54
14	6212.5	76	52
15	6075.0	76	52
16	5887.5	75	52
17	5850.0	75	51
18	5612.5	74	49
19	5637.5	74	50
20	5600.0	74	50
21	5637.5	74	50
22	5350.0	74	51
23	5075.0	74	51
24	5087.5	74	50
		74.75	

Control Week 1973 - November 2 (Fri)

Hour	KWHR	Inside Temp.	Outside Temp.
1	4925.0	74	50
2	4875.0	74	50
3	4850.0	74	50
4	4850.0	74	49
5	4787.5	74	48
6	9900.0	75	48
7	5100.0	75	48
8	5700.0	75	49
9	6175.0	75	51
10	6025.0	75	53
11	6000.0	76	55
12	6100.0	76	58
13	6112.5	76	60
14	6325.0	76	62
15	6187.5	76	62
16	6037.5	76	62
17	5712.5	76	61
18	5475.0	75	58
19	5325.0	75	55
20	5312.5	74	54
21	5412.5	74	53
22	5100.0	74	53
23	4887.5	74	53
24	4787.5	74	53
		74.88	

Control Week 1973 - November 3 (Sat)

Hour	KWHR	Inside Temp.	Outside Temp.
1	4550.0	74	53
2	4450.0	74	55
3	4425.0	74	56
4	4437.5	74	54
5	4412.5	74	54
6	4400.0	74	52
7	4537.5	75	50
8	5012.5	74	49
9	5400.0	74	50
10	5475.0	75	50
11	5412.5	75	52
12	5300.0	75	52
13	5025.0	75	52
14	4837.5	75	52
15	4837.5	75	52
16	4700.0	74	51
17	4625.0	75	49
18	4550.0	75	47
19	4612.5	75	46
20	4687.5	74	45
21	4650.0	74	44
22	4650.0	74	44
23	4587.5	74	44
24	4437.5	74	44
		74.42	

Control Week 1973 - November 4, (Sun)

Hour	KWHR	Inside Temp.	Outside Temp
1	4550.0	74	44
2	4512.5	74	43
3	4712.5	74	42
4	4812.5	74	41
5	4962.5	74	40
6	5025.0	74	39
7	5050.0	74	38
8	5100.0	74	39
9	5100.0	74	42
10	4850.0	74	44
11	4637.5	72	46
12	4375.0	72	48
13	4175.0	72	50
14	4012.5	72	51
15	3950.0	74	50
16	3975.0	74	49
17	4175.0	74	47
18	4500.0	74	44
19	4675.0	74	42
20	4875.0	74	41
21	5012.5	74	40
22	5150.0	73	35
23	5362.5	73	38
24	5500.0	73	37
		73.54	

Control Week 1973 - November 5 (Mon)

Hour	KWHR	Inside Temp.	Outside Temp
1	5562.5	72	37
2	5600.0	72	36
3	5637.5	72	35
4	5615.0	72	35
5	5687.5	72	36
6	6012.5	74	35
7	6675.0	74	33
8	6950.0	76	35
9	7587.5	76	39
10	7125.0	77	42
11	7000.0	77	45
12	6437.5	77	45
13	6526.0	76	47
14	6550.0	76	49
15	6362.5	76	48
16	6187.5	77	48
17	6000.0	77	46
18	5912.5	77	44
19	6037.5	76	43
20	6300.0	76	41
21	6412.5	76	40
22	6162.5	76	39
23	6125.0	76	38
24	6162.5	76	37
		75.25	

Control Week 1973 - November 6 (Tues)

Hour	KWHR	Inside Temp.	Outside Temp.
1	5987.5	76	37
2	6150.0	75	36
3	6137.5	75	36
4	6187.5	75	35
5	6137.5	75	35
6	6200.0	75	34
7	6550.0	76	33
8	7187.5	77	35
9	7687.5	77	38
10	7437.5	77	40
11	7062.5	77	41
12	7000.0	77	42
13	6812.5	78	42
14	6900.0	78	42
15	6862.5	78	42
16	6800.0	78	41
17	6775.0	78	40
18	6912.5	78	39
19	7112.5	78	38
20	7137.5	78	37
21	7100.0	78	36
22	6700.0	78	37
23	6612.5	78	38
24	6437.5	78	38
		77.0	

APPENDIX F

Example of Saving Variation with Outside Temperature

Example Building:

24 hr. Base Load	=	2000 KW
10 hr. Manufacturing Load	=	1000 KW
Heat Loss (Conduction and Air Change)	=	100 KW/°F of ΔT
Air Change Heat Loss at 1 Air Change per hour	=	75 KW/°F of ΔT

Calculations:

A. 60 °F ΔT

Load Required:

2000 KW + 1000 KW + 100 KW/°F · 60 °F

= 9000 KW

Savings for 10 °F thermostat lowering and cutting air change rate to ½ change per hour.

New Heat Loss is:

25 KW/°F (Conduction Loss) +

75 KW/°F (Air Change Loss) · 0.5

= 62.5 KW/°F

Thermostat Lowering Savings:

62.5 KW/°F x 10 °F = 625 KW

Air Change Savings is:

$0.5 \times 75\ KW/^{o}F \times 60\ ^{o}F = 1950\ KW$

Total Saved is:

2575 KW or 28.7%

B. For 50 ^{o}F ΔT

Total Load is:

$2000\ KW + 1000\ KW + 100\ KW/^{o}F \times 50\ ^{o}F$

$= 8000\ KW$

Thermostat Lowering Savings is:

$62.5\ KW/^{o}F \times 10\ ^{o}F = 625\ KW$

Air Change Savings is:

$0.5 \times 75\ KW/^{o}F \times 50\ ^{o}F = 1525\ KW$

Total Saved is 2250 KW

or 28.1%

C. For 30 ^{o}F ΔT

Total Load is:

$2000 + 1000\ KW + 100\ KW/^{o}F \times 30\ ^{o}F$

$= 6000\ KW$

Thermostat Savings is:

625 KW

Air Change Savings is:

$0.5 \times 75\ KW/^{o}F \times 30\ ^{o}F = 975\ KW$

Total Savings is:

1600 KW or 26.7%

Thesis
F2546 153101
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A case study for a large manufacturing plant.